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Doctoral Thesis

Individual Incentive and Pro-Environmental Behaviors: The Role of Networks

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Résumé de la Thèse

Faculté des Sciences Économiques et de Gestion

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Doctorat en Économie

Incitations Individuelles et Comportements Pro-Environnementaux : Le Rôle des Réseaux

Par

Tuyen Tong TIET

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La question fondamentale à laquelle sont confrontés les économistes et les écologistes est de savoir comment promouvoir de manière adéquate les comportements individuels favorables à l'environnement (c'est-à-dire motiver les gens à protéger leur environnement local ou à lutter contre le changement climatique mondial). En ce sens, diverses études théoriques et empiriques ont été élaborées pour expliquer comment les incitations monétaires (par exemple, les taxes, les subventions, etc.) ainsi que les incitations sociales (par exemple, l'influence sociale, les normes, etc.) pourraient contribuer à motiver les individus à adopter un comportement favorable à la durabilité environnementale. Dans le monde actuel, chacun est lié à plusieurs types de réseaux sociaux (par exemple, un réseau de famille, d'amis, de parents, de voisins, de collègues, etc.). En raison de ces liens, l'influence des pairs pourrait être utilisée pour motiver les individus à adopter un comportement cible (Thaler and Sunstein, 2008). Il est donc crucial de comprendre comment les incitations sociales (par exemple, les normes sociales, la comparaison sociale, les coups de coude, etc.) et la structure du réseau pourraient contribuer à promouvoir et à maintenir les comportements pro-environnementaux des individus.

Dans cette perspective, ce mémoire contribue à l'analyse du rôle du réseau et de son impact sur les comportements pro-environnementaux de manière théorique et expérimentale. Dans le premier chapitre de cette thèse, nous utilisons la méthode de la méta-analyse pour donner un aperçu de la force et de la pertinence de plusieurs facteurs d'incitation

sociale, comme l'influence sociale, le réseau et la confiance, sur les comportements pro-environnementaux des individus. Dans les deux chapitres suivants, nous développons des modèles théoriques pour étudier l'importance du réseau face à la nécessité d'encourager la conservation des ressources dans un jeu de ressources communes. Plus spécifiquement, dans le chapitre 2, nous étudions comment la comparaison sociale d'assimilation dans un réseau (c'est-à-dire que les personnes modifient leurs comportements afin de minimiser la différence/distance entre elles et les autres) pourrait avoir un impact sur les comportements des individus dans un jeu de ressources communes. Si le réseau du chapitre 2 est supposé être exogène (c'est-à-dire que le réseau est donné ou formé par le planificateur social central), au chapitre 3, nous analysons ensuite les impacts de l'influence sociale sur les comportements des individus dans un réseau endogène (c'est-à-dire que le réseau est formé par les individus eux-mêmes). Comme chaque agent doit payer un coût pour initier un lien avec d'autres, un lien peut être établi si et seulement si la condition de liaison est satisfaite (c'est-à-dire que le coût de la liaison est au moins inférieur ou égal à l'avantage pour les pairs).

Au chapitre 4, nous utilisons les données d'une expérience contextualisée en laboratoire sur le terrain dans le nord du Vietnam pour tester nos résultats théoriques. En particulier, nous étudions le rôle de la comparaison sociale (c'est-à-dire l'investissement dans l'agriculture biologique du groupe moyen) et du coup de pouce informationnel (c'est-à-dire l'information sur l'investissement socialement optimal de leurs voisins et d'eux-mêmes) dans différentes structures de réseau (par exemple, réseau vide, en étoile, en cercle ou complet) sur les décisions des agriculteurs en faveur de l'agriculture biologique. Enfin, le chapitre 5 étudie les préférences des agriculteurs pour l'agriculture biologique en utilisant la méthodologie de « l'expérience du choix discret » avec les agriculteurs du nord du Vietnam. En particulier, nous mesurons comment divers facteurs liés ou non au marché, notamment le rôle du réseau (par exemple, l'agriculteur du quartier pratiquant l'agriculture biologique), le contrat de vente, la formation et les conseils techniques, le rôle du chef (par exemple, les chefs formels ou/et informels pratiquant l'agriculture biologique) et le logo avec un code traçable, pourraient influencer les décisions des agriculteurs dans l'adoption de l'agriculture biologique.

Les résultats tant théoriques qu'expérimentaux suggèrent que le réseau joue un rôle important dans l'encouragement des comportements pro-environnementaux. Plus précisément, les politiques publiques, qui visent à promouvoir l'émergence de comportements pro-environnementaux, ne devraient pas se baser uniquement sur des subventions mais aussi plus essentiellement sur l'information donnée aux individus. Par exemple, il est essentiel que les individus comprennent bien l'importance de leurs liens sociaux, car un réseau de voisins et/ou d'amis peut être une source précieuse de connaissances, d'informations et de motivations qui contribue à encourager et à soutenir les comportements pro-environnementaux des individus (Van Campenhout et al., 2017). Nos résultats du réseau endogène indiquent également qu'un faible coût de connexion est nécessaire pour encourager la connexion au réseau et contribue ainsi à promouvoir la conservation des ressources. Les décideurs politiques et les individus eux-mêmes devraient donc toujours essayer d'établir un canal permettant aux individus de promouvoir les liens entre individus.

Toutefois, un faible coût de mise en relation peut contribuer à promouvoir la connexion au réseau, mais dans un réseau où chacun peut observer pleinement les comportements des autres, le fait de fournir aux individus la comparaison sociale (informations sur leur comportement moyen au sein du groupe/réseau) n'a pas d'impact significatif sur leurs comportements pro-environnementaux. En réalité, il est toujours très difficile d'observer la structure réelle du réseau, et les individus ne peuvent normalement pas observer pleinement les comportements, les actions ou les décisions de leurs voisins. Dans cette situation, fournir une comparaison sociale aux individus pourrait stimuler l'auto-évaluation ainsi que la concurrence, et pourrait donc contribuer à les inciter à se comporter positivement envers les comportements pro-environnementaux (Festinger, 1954).

Notre modèle théorique suggère également que nous pouvons promouvoir efficacement la conservation des ressources communes en encourageant l'assimilation de la comparaison sociale dans les réseaux centralisés (comme un réseau en étoile) par rapport aux réseaux décentralisés (comme un cercle ou un réseau complet). Cela signifie que dans un monde social, où un agent central peut jouer un rôle dans la motivation des autres (par exemple, un leader, une personne influente), encourager la comparaison d'assimilation ainsi que motiver le rôle de l'agent central pourrait aider à promouvoir de manière significative la conservation des ressources communes. Outre les relations entre individus, les décideurs politiques devraient également prendre en compte le rôle de "leader environnemental" qui fait le premier pas dans la création d'une prise de conscience, d'une sensibilisation et d'une action en faveur de la protection de l'environnement (Akiyama et al., 2013). Parce qu'un responsable environnemental pourrait jouer un rôle d'exemple et de modèle pour les autres, il ou elle pourrait donc contribuer à pousser efficacement les individus vers un environnement plus durable.

Notre analyse révèle que le traitement "comparaison sociale et coup de pouce informationnel" a un impact positif sur la décision de l'agriculteur d'investir dans l'agriculture biologique, quel que soit le type de réseau. Ce résultat suggère donc que les décideurs politiques devraient rappeler aux agriculteurs, en temps utile, non seulement l'importance de l'agriculture biologique, mais aussi l'investissement biologique socialement optimal (c'est-à-dire le coup de pouce à l'information), car il peut contribuer à sensibiliser les agriculteurs à l’agriculture biologique et les aider à respecter leurs engagements et leurs calendriers (Fabregas et al., 2019). Elle les incite donc à combler le fossé entre leurs intentions et leurs actions.

Bibliography

Akiyama, T., K. J. An, H. Furumai, and H. Katayama (2013). The concept of environmental leader. In *Environmental Leadership Capacity Building in Higher Education*, pp. 19–40. Springer, Tokyo.

Fabregas, R., M. Kremer, and F. Schilbach (2019). Realizing the potential of digital development: The case of agricultural advice. *Science 366*(6471), 1–9.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations 7*(2), 117–140.

Thaler, R. and C. Sunstein (2008). *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Van Campenhout, B., W. Walukano, F. Nattembo, L. Nazziwa-Nviiri, and J. Blom (2017). The role of Information in agricultural technology adoption: Experimental evidence from rice farmers in Uganda. *IFPRI Discussion Paper Series 01684/2017*, 1–47.

Abstract of thesis entitled

Individual Incentive and Pro-Environmental Behaviors: The Role of Networks

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The fundamental issue faced by both economist and environmentalist scholars is how to adequately promote individual pro-environmental behaviors (i.e., motivating people to either protect their local surrounding environment or fight against global climate change). In this sense, a variety of theoretical and empirical studies has been developed to explain how monetary (e.g., tax, subsidy, etc.) as well as social incentives (e.g., social influence, norms, etc.) could help to motivate individuals to behave toward environmental sustainability. In a more and more connected world today, everyone is linked to a social network (e.g., a network of family, friends, relatives, neighbors, co-workers, etc.). Since individuals are linked to each other, peer influence could be used to motivate individuals to perform a target behavior (Thaler and Sunstein, 2008). It is therefore crucial to understand how social incentives (e.g., social norms, social comparison, nudges, etc.) and network structure could help to promote and to sustain individuals' pro-environmental behaviors.

In this perceptive, this dissertation contributes to the analysis of the role of network and its impact on pro-environmental behaviors in both theoretical and experimental ways. In the first chapter of this dissertation, we use the meta-analysis method to provide insights into the strength and relevance of several social incentive factors, including social influence, network and trust, on individuals' pro-environmental behaviors. In the following two chapters, we develop theoretical models to investigate the role of network structure in encouraging the resource conservation in a common pool resource game. More specifically, in Chapter 2, we study how network and assimilation social comparison (i.e., ones change their behaviors in order to minimize the difference/distance between them and others) could impact individuals' behaviors in a common pool resource game. If the network in Chapter 2 is assumed to be exogenous (i.e., network is given or formed by the central social planner), in Chapter 3, we then analyze the impacts of social influence on individuals' behaviors in an endogenous network (i.e., network is formed by individuals

themselves). Since each agent has to pay a cost to initiate a link with others, a link can be established if and only if the linking condition is satisfied (i.e., the cost of linking is at least less than or equal to the peer benefit).

In Chapter 4, we use a data from a contextualized lab-in-the-field experiment in Northern Vietnam to test our theoretical results. In particular, we investigate the role of social comparison (i.e., the average group's organic investment) and information nudge (i.e., information about the socially optimal investment of their neighbors and themselves) in different network structures (e.g., empty, star, circle or complete network) on farmers' decisions in organic farming investment. Finally, Chapter 5 studies farmers' preferences toward organic farming using discrete choice experiment with also farmers in Northern Vietnam. In particular, we aim to measure how various market and non-market factors including role of network (i.e., neighborhood farmer doing organic farming), sale contract, training and technical advice, role of leader (i.e., formal or/and informal leaders doing organic farming) and logo with traceable code could influence farmers' decisions in adopting organic farming.

The both theoretical and experimental results suggest that the network plays an important role in encouraging the pro-environmental behaviors. More specifically, public policies, which aim to promote the emergence of pro-environmental behavior, should not be based only on subsidies but also more essentially on information given to individuals. For instance, it is crucial for individuals to understand well the importance of their social links since for example, a network of neighbors or/and friends could be a valuable source of knowledge, information and motivations that helps to incentivize and sustain individual's pro-environmental behaviors (Van Campenhout et al., 2017). Our results of the endogenous network also indicate that a low cost of linking is necessary to encourage the network connection and thus it helps to promote resource conservation. Policymakers and individuals themselves should therefore always try to establish a channel for individuals to promote individual-to-individual links.

However, a low cost of linking can help to promote the network connection, but in a network where everyone can fully observe others' behaviors, providing individuals the social comparison (information about their average group/network behavior) has no significant impact on their pro-environmental behaviors. In reality, it is always very difficult to observe the actual network structure, and individuals cannot fully observe the behaviors, actions or decisions of their neighbors. In this situation, providing information that encourages the social comparison to individuals could stimulate self-evaluation as well as competition, and could thus help to incentivize them to behave positively towards the environment (Festinger, 1954).

Our theoretical model also suggests that we can effectively promote the common pool resource conservation by encouraging the assimilation social comparison in a centralized network (like a star network) compared to decentralized networks (like a circle or complete network). This means that in a social world, where there is a central agent who can plays a role in motivating others (e.g., a leader, an influencer or an influential person), encouraging the assimilation comparison as well as motivating the role of the central agent could help to significantly promote the common resource conservation. Therefore, in addition to individual-to-individual relationships, policymakers should also take the role of "environmental leader" who takes the first step in creating consciousness, awareness and action on protecting the environment into account (Akiyama et al., 2013). This is because an environmental leader could play a role as an example and model to others, he or she could therefore help to effectively drive individuals toward a more sustainable environment.

Our analysis reveals that the treatment "social comparison and information nudge" can positively influence farmers' decisions in adopting organic farming regardless of the types of network. This result therefore suggests that policymaker should provide farmers timely reminders about not only the importance of organic agriculture but also the socially optimal organic investment (i.e., information nudge) since it can help to increase farmers' awareness about organic agriculture and to help them to maintain commitments and schedules (Fabregas et al., 2019). As a result, it helps to nudge them towards bridging the gap between their intentions and their actions.

Bibliography

Akiyama, T., K. J. An, H. Furumai, and H. Katayama (2013). The concept of environmental leader. In *Environmental Leadership Capacity Building in Higher Education*, pp. 19–40. Springer, Tokyo.

Fabregas, R., M. Kremer, and F. Schilbach (2019). Realizing the potential of digital development: The case of agricultural advice. *Science 366*(6471), 1–9.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations 7*(2), 117–140.

Thaler, R. and C. Sunstein (2008). *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Van Campenhout, B., W. Walukano, F. Nattembo, L. Nazziwa-Nviiri, and J. Blom (2017). The role of Information in agricultural technology adoption: Experimental evidence from rice farmers in Uganda. *IFPRI Discussion Paper Series 01684/2017*, 1–47.

Individual Incentive and Pro-Environmental Behaviors: The Role of Networks

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Declaration

I, Tuyen Tong TIET, declare that this thesis titled, "Individual Incentive and Pro-Environmental Behaviors: The Role of Networks", which is submitted in fulfillment of the requirements for the Degree of PhD in Economics, represents my own work except where due acknowledgement have been made. I further declared that it has not been previously included in a thesis, dissertation, or report submitted to this University or to any other institution for a degree, diploma or other qualifications.

Signed: ______________________

Date: January 14, 2021

I dedicate this thesis to my darling, Thi, and my beloved family for their constant support and unconditional love.

I love you all dearly.

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Tuyen Tong TIET
University of Strasbourg
January 14, 2021

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List of Abbreviations

CL	**C**onditional **L**ogit Model
CPRs	**C**omon **P**ool **R**esources
FE	**F**ixed **E**ffect
HCM	**H**ybrid **C**hoice **M**odel
LR	**L**ikelihood **R**atio
MNL	**M**ulti-**N**omial **L**ogit
PCC	**P**artial **C**orrelation **C**oefficient
PG	**P**ublic **G**ood
RE	**R**andom **E**ffect
RPL	**R**andom **P**arameter **L**ogit
SC	**S**ocial **C**omparison Treatment
SC & Nudge	**S**ocial **C**omparison Combined with Information **Nudge** Treatment
SE	**S**tandard **E**rror
SEpcc	**S**tandard **E**rror of the Partial correlation coefficient
WTP	**W**illingness **T**o **P**ay

Chapitre 0

Introduction

0.1 Motivation de la thèse

La compréhension du comportement individuel est non seulement importante en sociologie, en psychologie et en marketing, mais aussi un objectif fondamental des économistes et des environnementalistes. La question fondamentale à laquelle sont confrontés les économistes et les environnementalistes est de savoir comment promouvoir de manière adéquate un "*comportement pro-environnemental*" (par exemple, comment motiver efficacement les gens à protéger leur environnement local ou à lutter contre le changement climatique mondial). "*Comportement pro-environnemental*" fait référence à un comportement qui pourrait soit bénéficier à l'environnement, soit nuire à l'environnement, mais le moins possible (Steg and Vlek, 2009). En ce sens, divers modèles théoriques et travaux empiriques ont été élaborés pour étudier l'impact des incitations monétaires et non monétaires (c'est-à-dire sociales) sur les comportements individuels pro-environnementaux (Kollmuss and Agyeman, 2002; Clark et al., 2003; Allcott and Rogers, 2014; Diederich and Goeschl, 2014; Lazaric et al., 2019; Schwartz et al., 2020). De nombreuses études ont prouvé que les incitations tant monétaires que sociales pouvaient avoir un impact significatif sur le comportement individuel pro-environnemental. Par exemple, l'octroi de paiements (i.e., paiements pour des services écosystémiques, programme agroenvironnemental, etc.) (Espinosa-Goded et al., 2010; Robert and Stenger, 2013; Krawczyk et al., 2016), le feedback social (i.e., le rapport sur la consommation des ménages) (Allcott and Rogers, 2014; Brülisauer et al., 2020) ou des coups de coude (Schubert, 2017; Lefebvre and Stenger, 2020) pourrait contribuer à encourager les gens à protéger l'environnement en consommant moins d'énergie, d'eau ou en recyclant davantage, etc..

Toutefois, le fait de se concentrer sur des incitations monétaires ou sociales lorsqu'on aborde des questions environnementales peut soulever plusieurs problèmes: par exemple, une personne qui prend une mesure pour atténuer son sentiment d'obligation de contribuer à l'amélioration de la qualité de l'environnement peut ensuite ne pas prendre d'autres mesures lorsqu'elle se rend compte que les autres ne coopèrent pas. On pourrait définir cela comme un biais d'action unique. En outre, pour la plupart des questions environnementales (par exemple, la biodiversité, la déforestation, l'énergie, etc.), il est nécessaire d'avoir de nombreux individus, mais le plus souvent au sein d'une même zone, qui adhèrent à un programme de conservation afin d'atteindre un seuil nécessaire (proportion d'individus dans le réseau) au-dessus duquel un effet positif du programme peut se produire. Ainsi, plusieurs études suggèrent que les facteurs de réseau peuvent également être utilisés pour promouvoir des "comportements pro-environnementaux collectifs", qui sont des comportements pris ensemble par un groupe d'individus et incluant la société dans son ensemble (c'est-à-dire des actions collectives) pour atteindre un objectif environnemental (Gouu, 1993; Van Laerhoven, 2010).

Ces dernières années, le concept de "réseau social et économique" (par exemple, la manière dont la structure du réseau affecte les comportements) a été développé et a attiré beaucoup plus d'attention des décideurs politiques ainsi que des chercheurs (Jackson, 2010; Jackson et al., 2017). Notez que la structure de réseau ou structure sociale est une structure composée d'acteurs sociaux (par exemple, des individus ou des organisations) et de liens/attaches sociaux (c'est-à-dire des interactions ou des connexions entre acteurs) (Marsden and Lin, 1982; Scott, 1988). Par exemple, dans leurs études, les auteurs ont montré que les décisions des individus dans l'exécution d'un comportement/d'une action pouvaient donc être influencées collectivement par les comportements des autres dans un réseau (c'est-à-dire les comportements collectifs) (Bramoullé et al., 2007; Jackson, 2010). En outre, plusieurs études, qui ne sont pas liées aux réseaux, ont également indiqué qu'au lieu de prendre une décision indépendante, les individus considèrent souvent l'utilité des autres et les prennent en compte dans leur processus de décision (c'est-à-dire en tenant compte des préférences "autres") (Bolton and Ockenfels, 2000; Grund et al., 2013). D'autres études ont également suggéré que les humains se soucient réellement des autres, en particulier lorsqu'ils sont liés à d'autres personnes dans un réseau (par exemple, un réseau d'amis, de collègues, de voisins, etc.) (Dufwenberg et al., 2011; Grund et al., 2013). Par conséquent, le rôle des réseaux pourrait être considéré comme un facteur important, qui peut être utilisé pour motiver les individus à adopter un comportement positif vis-à-vis de l'environnement (c'est-à-dire des comportements pro-environnementaux).

Ces dernières années, plusieurs études ont été menées pour étudier le rôle des réseaux dans la promotion de comportements pro-environnementaux : comment l'interaction sociale dans les réseaux (c'est-à-dire l'interaction des uns avec les autres dans un réseau) pourrait affecter les comportements des agriculteurs en cas de restriction des pratiques intensives (Polman and Slangen, 2008); comment le partage d'informations et les messages environnementaux par le biais du réseau pourraient encourager la conservation des ressources (Mantilla, 2015; Barnes et al., 2016; Mekonnen et al., 2017); et si les individus qui se soucient les uns des autres (c'est-à-dire les préférences des autres) pourraient influencer les intentions des individus de participer ou non à des groupes environnementaux (Cho et al., 2013; Cho and Kang, 2017). Toute cette littérature existante suggère que les réseaux pourraient donc jouer un rôle important en incitant les individus à se comporter de manière positive envers la durabilité environnementale. Bien que plusieurs recherches aient été menées pour étudier le rôle des réseaux sur les comportements pro-environnementaux des individus, il reste encore de nombreuses questions que la littérature existante a laissées ouvertes. En d'autres termes, alors que la majorité des études existantes se sont concentrées sur la manière dont l'interaction sociale et l'information par le biais des réseaux pourraient motiver le changement de comportement individuel, une poignée de recherches étudie comment le fait de fournir des incitations sociales (par exemple, comparaison sociale, encouragement à l'information, etc.) aux individus dans différentes structures de réseau pourrait effectivement encourager leurs comportements pro-environnementaux. Par conséquent, l'objectif principal de cette thèse est de fournir un aperçu des impacts des incitations sociales dans les réseaux sur les comportements pro-environnementaux individuels.

En outre, si certaines études ont déjà porté sur les changements de résultats environnementaux liés à des modifications de la structure des réseaux, peu d'attention a été accordée aux effets des comportements pro-environnementaux individuels sur l'émergence des réseaux. La théorie du "principe de l'homophilie" indique que les individus qui se comportent de manière similaire ont tendance à vivre dans une même forme de société en raison de la sélection sociale (c'est-à-dire des individus ayant des caractéristiques similaires telles que, même ethnicité, sexe, race, âge et statut social) (McPherson et al., 2001). En conséquence, l'offre d'incitations sociales par le biais des réseaux pourrait faire en sorte que des personnes qui ne sont pas (ou qui étaient déjà) dans la communauté auparavant puissent être influencées par d'autres et décider d'entrer (ou de sortir) du réseau ou de la communauté. Par conséquent, si le changement de comportement individuel a également un impact sur l'émergence des réseaux, il est important d'étudier comment les incitations sociales dans le réseau exogène (c'est-à-dire la structure du réseau est donnée) et dans le réseau endogène (c'est-à-dire la structure du réseau n'est pas donnée et les individus peuvent décider avec qui ils formeront un lien) pourraient aider à promouvoir et à maintenir le comportement pro-environnemental.

En résumé, cette thèse vise à contribuer à la littérature existante en étudiant en profondeur les impacts des incitations sociales dans les réseaux et leur impact sur les comportements pro-environnementaux, y compris la conservation des ressources et l'investissement dans l'agriculture biologique. En particulier, nous nous concentrons sur l'analyse des impacts des incitations sociales dans différents réseaux exogènes (par exemple, réseau en étoile, en cercle et complet) et endogènes (c'est-à-dire que la structure du réseau n'est pas donnée) de manière théorique et empirique. Nous développons des modèles théoriques pour étudier les comportements individuels dans un jeu de ressources communes qui prend en compte à la fois le réseau exogène (c'est-à-dire que le réseau est donné ou formé par le planificateur social central) et le réseau endogène (c'est-à-dire que le réseau est formé par les individus eux-mêmes). Nous effectuons également une expérience contextualisée de laboratoire sur le terrain (lab-in-the-field) et une application de la méthode des choix discrets pour étudier comment la promotion des réseaux ainsi que la fourniture de différents types d'incitations sociales (par exemple, la comparaison sociale et les informations) dans différents types de réseaux (par exemple, cercle, étoile, réseau complet, etc.) pourraient avoir un impact sur le comportement individuel dans l'adoption de l'agriculture biologique. Ces questions sont étudiées plus spécifiquement dans les cinq chapitres suivants.

- Le chapitre 1 donne un aperçu de la force et de la pertinence de plusieurs facteurs d'incitation sociale dans la promotion d'un comportement pro-environnemental. En particulier, nous avons utilisé une méta-analyse pour évaluer l'efficacité de sept groupes d'incitations sociales : l'influence sociale interne et externe, les facteurs liés aux réseaux, notamment la taille des réseaux, les connexions et le leadership des réseaux et la confiance, notamment la confiance dans les institutions et la confiance dans les autres, qui peuvent promouvoir un comportement favorable à l'environnement.
- Le chapitre 2 étudie théoriquement le rôle de la comparaison sociale dans différentes structures de réseau pour encourager le comportement individuel de conservation dans un jeu de ressources en commun (c'est-à-dire le RPC). Plus précisément, nous étudions comment l'assimilation dans la comparaison sociale (c'est-à-dire le changement de comportement afin de s'intégrer à un groupe) dans différentes structures de réseau, y compris un réseau vide, une étoile, un cercle et un réseau complet, pourrait aider à promouvoir la conservation des ressources de la réserve commune.
- Le chapitre 3 étudie théoriquement comment l'influence sociale (c'est-à-dire la conservation des ressources du quartier) dans la situation de réseau endogène (c'est-à-dire que le réseau est formé par les individus eux-mêmes) pourrait avoir un impact sur les comportements individuels dans un jeu de ressources communes. Dans notre modèle, les agents doivent choisir simultanément leur niveau d'effort pour extraire la ressource et le nombre de voisins à relier afin de maximiser leurs gains. Ainsi, puisque le réseau est endogène, il est intéressant d'observer à quel niveau d'influence sociale, de coût de liaison et de taille du réseau, le système d'un jeu de RPC (c'est-à-dire l'équilibre entre l'extraction et la connexion au réseau) sera localement stable (conservation durable) et instable (destruction de la RPC).
- Le chapitre 4 explore le rôle de la comparaison sociale (c'est-à-dire l'information sur

l'investissement en agriculture biologique moyen du groupe) et du coup de pouce informationnel (c'est-à-dire l'information sur l'investissement socialement optimal de leurs voisins et d'eux-mêmes) dans différentes structures de réseau (p. ex. réseau vide, étoile, cercle et réseau complet) sur les décisions des agriculteurs d'investir dans l'agriculture biologique par le biais d'une expérience contextualisée de laboratoire sur le terrain dans le nord du Vietnam.

- Le chapitre 5 étudie les préférences des agriculteurs pour l'agriculture biologique en utilisant une expérience de choix discret avec des agriculteurs du nord du Vietnam. En particulier, nous mesurons comment divers facteurs liés au marché (notamment le contrat de vente et le logo avec un code traçable) et facteurs non liés au marché (notamment le rôle des réseaux (c'est-à-dire l'agriculteur de quartier pratiquant l'agriculture biologique), la formation et les conseils techniques, le rôle de leader (c'est-à-dire les leaders formels et/ou informels pratiquant l'agriculture biologique)) pourraient influencer les décisions des agriculteurs dans l'adoption de l'agriculture biologique.

0.2 Incitations sociales dans la promotion de comportements pro-environnementaux

Les incitations sont utilisées pour motiver les individus à se comporter d'une manière socialement souhaitable. Du point de vue de l'économie de l'environnement, il existe deux types d'incitations différentes : les incitations monétaires et les incitations non monétaires. Par exemple, la taxe pigouvienne est une incitation monétaire (c'est-à-dire économique), développée par Pigou en 1920, qui est utilisée pour encourager les pollueurs à réduire leurs émissions polluantes (Baumol, 1972). De même, le système de plafonnement et d'échange est également une incitation monétaire, qui est utilisée pour inciter les acteurs polluants à réduire leurs émissions en fournissant aux entreprises un plafond/un quota initial sur les émissions de gaz à effet de serre ainsi qu'en leur permettant d'acheter ou de vendre leurs quotas. La littérature existante suggère que les incitations monétaires pourraient inciter fortement les particuliers ou les secteurs privés à économiser de l'argent en réduisant leurs émissions (Schmalensee and Stavins, 2017).

Toutefois, en réalité, la mise en œuvre des incitations monétaires se heurte également à de nombreuses difficultés. Le premier problème, rencontré par les économistes lors de l'élaboration de divers instruments et réglementations en matière de pollution, est la contrainte d'information. Par exemple, dans le cas de la pollution "diffuse" (c'est-à-dire la pollution de source non ponctuelle), il est très difficile d'observer parfaitement les émissions produites par les différents acteurs polluants (O'Shea, 2002). Par conséquent, plusieurs études ont indiqué que la mesure précise des émissions est très coûteuse, voire impossible. Deuxièmement, l'effet des politiques monétaires n'est pas toujours durable à long terme (Ashenmiller, 2011; Lefebvre and Stenger, 2020). Plusieurs études ont montré que les programmes de conservation de l'environnement ne peuvent pas être facilement réalisés s'ils ne tiennent pas compte des facteurs sociaux (par exemple, l'influence sociale, les normes, etc.) ainsi que des facteurs socio-psychologiques individuels (par exemple, les attitudes à l'égard des comportements pro-environnementaux ou la préoccupation concernant les impacts négatifs de l'environnement, etc. (Pelletier et al., 1999). Par exemple, les gens peuvent ne pas continuer à faire plus d'efforts pour protéger l'environnement (par exemple, recycler, économiser l'énergie, etc.) s'ils constatent que leurs voisins ou amis ne le font pas (Kollmuss and Agyeman, 2002; Thomas and Sharp, 2013).

C'est depuis plus récemment en économie que les incitations non monétaires ou sociales y compris les certificats, les labels, les réactions sociales et l'influence sociale, ont été largement évaluées par de nombreux chercheurs (Bjørner et al., 2004; Klooster, 2005; Nolan et al., 2008). Dans une étude, les auteurs ont montré que la certification forestière contribue avec succès à promouvoir la gestion durable des forêts et le maintien de la biodiversité sur 124 millions d'hectares (3.2%) de forêts dans le monde (Rametsteiner and Simula, 2003). À cet égard, les incitations sociales pourraient être considérées comme des instruments appropriés et potentiels pour promouvoir la durabilité environnementale. Toutefois, dans leur étude, les auteurs ont également fait valoir que la certification n'améliorerait pas la compétitivité des industries qui ont déjà eu un contrôle strict de la gestion forestière (Rametsteiner and Simula, 2003). En d'autres termes, même les bonnes politiques environnementales qui ont déjà été mises en œuvre avec succès dans plusieurs communautés pourraient être confrontées à un échec dans certains autres domaines. Un autre exemple à prendre en considération est le changement climatique mondial, qui nécessite des actions collectives entre les pays pour s'attaquer au problème du climat mondial (Ostrom, 2010). Ainsi, les pays feront-ils des efforts pour réduire les émissions de gaz à effet de serre ou seront-ils incités à profiter des comportements constructifs des pays voisins? En d'autres termes, un objectif environnemental peut ne pas être facilement atteint si nous ne motivons pas les gens à se comporter de manière positive et collective en faveur de la durabilité environnementale.

Par conséquent, dans le premier chapitre, nous utilisons la méta-analyse de 125 études existantes pour mettre en lumière la force et la pertinence de sept groupes d'incitations sociales (influence sociale externe et interne, réseau y compris la taille du réseau, connexion au réseau et leadership et confiance y compris la confiance dans les institutions et la confiance dans les autres) dans la promotion des comportements pro-environnementaux.

0.2.1 Chapitre 1 : Facteurs d'incitation sociale dans les interventions visant à promouvoir des comportements durables : Une méta-analyse

Sur la base d'une méta-analyse, ce chapitre met en évidence la force et la pertinence de plusieurs facteurs d'incitation sociale en ce qui concerne le comportement pro-environnemental, notamment l'influence sociale, les facteurs liés aux réseaux (comme la taille du réseau, la connexion au réseau et le leadership), la confiance dans les autres et la confiance dans les institutions. En particulier, l'influence sociale interne est définie comme des motifs internes tels que les attitudes, les normes personnelles, la motivation intrinsèque ou l'auto-évaluation/amélioration résultant du processus de concurrence sociale. L'influence sociale externe est définie comme des motifs externes tels que la motivation extrinsèque, l'attente des autres ou les normes sociales pour les individus ou la société sur ce qu'ils doivent faire. Les facteurs de réseau comprennent la connexion au réseau (degré de connexion entre les individus), la taille du réseau (nombre d'individus dans le réseau) et le leadership (présence d'un leader dans le réseau). La connexion au réseau est le degré de connexion ou la relation entre les individus et les autres, y compris les amis, les voisins, les environnementalistes et les organisations environnementales. La taille du réseau saisit le nombre d'amis, de voisins ou de collègues impliqués dans des actions pro-environnementales ou des associations environnementales auxquelles les individus participent. La présence d'un leader dans un réseau pourrait contribuer à promouvoir les comportements pro-environnementaux de ses adeptes. La confiance comprend la confiance dans les institutions (gouvernement, institutions publiques, etc.) et la confiance dans les autres (amis, voisins, famille, etc.).

L'ensemble de données de notre étude a été construit en utilisant les bases de données Web of Science, Google Scholar, PubMed, SagePub et ScienceDirect, ainsi que d'autres sites web de revues pertinentes. Grâce à des recherches systématiques par mots clés, nous avons d'abord effectué l'analyse des résumés et recueilli toutes les études empiriques, y compris les travaux publiés et non publiés (plus de 1500 articles). Nous avons éliminé tous les articles qui ne fournissaient pas suffisamment d'informations pour calculer les erreurs types de la taille de l'effet (c'est-à-dire les valeurs t, les valeurs p, les intervalles de confiance ou les niveaux de signification). Nous avons finalement obtenu 125 études lors de la dernière étape. Ces 125 études ont abouti à 185 observations dans nos données de méta-analyse (dans certains articles, les auteurs ont utilisé plus d'une variable sociale pour examiner les impacts sur le comportement pro-environnemental).

Premièrement, nos résultats suggèrent que l'influence sociale est nécessaire pour l'émergence de comportements pro-environnementaux. Plus précisément, l'influence sociale interne (c'est-à-dire qui incite les gens à modifier leurs perceptions et leurs attitudes) est très importante pour promouvoir les comportements pro-environnementaux. Outre l'influence sociale interne, nos résultats suggèrent également que l'influence sociale externe a un impact positif sur les comportements pro-environnementaux, mais qu'elle est moins efficace que les influences internes. Ce résultat est conforme à la littérature existante selon laquelle les motivations sociales internes sont meilleures que les motivations externes parce qu'elles guident les gens à modifier leurs comportements, tandis que les influences externes peuvent pousser les gens à effectuer une certaine action par le biais de la conformité et de l'identification, mais cela ne suffit pas à les motiver à modifier leurs perceptions et leurs attitudes à l'égard d'un comportement durable. Cette constatation implique que les impacts d'une politique environnementale peuvent être sous-estimés si les décideurs politiques n'incluent pas l'influence sociale dans leurs décisions concernant les questions environnementales.

Deuxièmement, la connexion en réseau encourage les comportements pro-environnementaux, ce qui signifie que l'efficacité d'une politique de conservation peut être améliorée si les connexions entre les individus sont accrues. Ce résultat n'étaye pas une conjecture existante qui suppose que l'augmentation des interactions entre les individus dans une grande structure peut être néfaste pour le comportement de conservation sociale. Enfin, la confiance dans les institutions peut dicter le comportement des individus d'une manière qui pourrait influencer la conception des politiques et générer les résultats souhaités. En d'autres termes, le succès d'une politique environnementale dépend en grande partie de la confiance dans les institutions par une transparence accrue, une stratégie de communication et une interaction avec les populations, etc.

0.3 Le rôle des réseaux dans la promotion d'un comportement pro-environnemental : Approches théoriques

Plusieurs études ont démontré que les liens entre les personnes seraient liés aux liens entre leurs comportements (Jackson, 2010; Centola, 2010; Gould et al., 2019). La littérature existante indique également que les décisions des individus peuvent être influencées par d'autres, même sans en avoir conscience (Cialdini, 1987; Nisbet et al., 2009). Ces dernières années, de nombreuses études théoriques ont été menées pour étudier l'impact des réseaux sur le comportement des individus : la relation entre les réseaux et les contributions individuelles au bien public est celle qui a retenu le plus l'attention des chercheurs (Bramoullé et al., 2007; Santos et al., 2008; Jackson, 2010); le réseau joue un rôle clé dans la promotion des comportements pro-sociaux (Frey and Meier, 2004); modèle de réseau social des effets des pairs dans les décisions pénales (Patacchini and Zenou, 2012). Certaines études ont mis l'accent sur le rôle des réseaux dans la promotion de comportements pro-environnementaux. Par exemple, la diffusion de messages environnementaux dans différents réseaux pourrait contribuer à encourager la conservation des ressources de la réserve commune (Mantilla, 2015) et la manière dont l'information se diffuse dans les différents réseaux pourrait contribuer à réduire les prises accessoires de poissons (Barnes et al., 2016).

Bien que le modèle de réseau ait été largement étudié dans la littérature sur le jeu d'intérêt public, quelques preuves théoriques ont été trouvées dans l'étude du rôle des réseaux dans la promotion de la conservation des ressources individuelles dans le jeu d'intérêt public. Tout comme les biens publics, les ressources communes ne sont pas non plus exclusives. Toutefois, une différence majeure entre elles est la propriété de rivalité : le bien public peut être consommé sans réduire la disponibilité pour les autres, tandis que la consommation de ressources communes réduira les ressources disponibles pour les autres (c'est-à-dire la propriété de soustraction). En conséquence, alors que les biens publics peuvent souffrir d'un problème de resquillage en raison du manque de contributions, les ressources communes seraient autrement confrontées à un problème de "tragédie des biens communs" en raison de la surexploitation (Hardin, 1968). Ces propriétés (excluabilité et soustractibilité) rendent donc la gestion des ressources communes (RPC) particulièrement complexe car il est difficile d'empêcher les gens de soustraire des unités d'une RPC (par exemple, forêt, océan, pêche, atmosphère, etc.).

Bien que plusieurs ouvrages existants soutiennent la théorie de Hardin (c'est-à-dire la théorie de la tragédie des biens communs) par le libre accès aux ressources naturelles, cela conduirait sans aucun doute au problème de la surexploitation (Bromley and Cernea, 1989; Pearce and Turner, 1990), Ostrom a fait valoir que l'on pouvait parvenir à une gestion efficace des RPC grâce aux droits de propriété et aux réglementations gouvernementales (Ostrom et al., 1994). Par exemple, dans son livre, Ostrom a également catalogué plusieurs exemples où des communautés ont géré avec succès les CPR sans aucune aide du gouvernement central, des bergers alpins du 16ème siècle gérant les pâturages à l'année 1980 des villages japonais gérant les forêts communales (Ostrom, 1990). Suite à l'étude d'Ostrom, Chaudhuri (2011); Bowles and Gintis (2011) et bien d'autres, ont suggéré que la coopération humaine dans la gestion du commun pourrait émerger et persister sous des institutions stables.

En outre, certaines études ont montré que les gens sont prêts à contribuer à un bien public s'ils savent que d'autres y contribuent également (c'est-à-dire une coopération conditionnelle) (Arrow, 1970; Frey and Meier, 2004). En ce sens, certains peuvent être motivés à réduire leurs extractions de RPC s'ils observent les efforts de conservation des autres. Les autres pourraient représenter d'autres personnes de la communauté ou leurs amis (ou voisins) proches (c'est-à-dire ceux avec lesquels ils sont en contact). Plusieurs études empiriques ont indiqué que les réseaux pourraient jouer un rôle important dans l'atténuation du problème de la surextraction (c'est-à-dire de la "tragédie des biens communs"), en particulier lorsque les populations dépendent fortement de biens communs, sont très proches les unes des autres et ont des liens sociaux durables (Cárdenas et al., 2015). D'autres études ont montré que le partage d'informations par le biais d'un réseau social pouvait contribuer à limiter l'extraction de ressources (Barnes et al., 2016). Le réseau social est donc un bon point de départ pour expliquer comment les individus pourraient se comporter de manière pro-environnementale en vue de la conservation des ressources communes.

C'est pourquoi, dans les chapitres 2 et 3, nous nous proposons d'étudier le rôle des réseaux dans l'encouragement des comportements de conservation des ressources dans le cadre du jeu des ressources en commun. En particulier, notre objectif dans le chapitre 2 est d'étudier comment l'assimilation en comparaison sociale (c'est-à-dire que les individus comparent leurs comportements avec ceux de leurs voisins directs) dans différents types de réseaux (par exemple, cercle, étoile ou réseau complet, etc.) a un impact sur les comportements des individus dans l'extraction d'une ressource commune. Dans le chapitre 3, nous étudions également le comportement de conservation des individus dans le jeu de la ressource commune en prenant en compte l'influence sociale (c'est-à-dire que les individus bénéficient de leur effort de conservation du voisinage) dans le réseau endogène. Dans ce chapitre, le réseau ne sera pas donné par le planificateur central mais il sera formé par les individus eux-mêmes (c'est-à-dire le réseau endogène), les agents doivent payer un coût pour initier un lien avec d'autres et un lien est établi si et seulement si le coût du lien est inférieur au bénéfice du lien (c'est-à-dire la condition de lien).

0.3.1 Chapitre 2 : Comparaison sociale dans les réseaux : Un jeu de ressources communes

Cette étude examine comment l'assimilation en comparaison sociale (c'est-à-dire le changement de comportement afin de s'intégrer à un groupe) dans différentes structures de réseau (c'est-à-dire réseau vide, en étoile, en cercle et complet) pourrait avoir un impact sur les comportements individuels dans l'extraction d'une ressource commune. L'assimilation est le moment où un individu peut identifier les similitudes entre lui et les autres, tandis que le contraste fait référence à l'admiration/estime de soi accrue que l'on obtient après s'être éloigné des autres (Kühnen and Hannover, 2000).

Dans notre modèle, nous considérons que les individus se soucient du comportement des agents avec lesquels ils sont en contact (c'est-à-dire leurs amis ou leurs voisins). En d'autres termes, chaque agent est situé dans un réseau donné et il compare son action à celle de ses voisins directs (c'est-à-dire comparaison sociale dans le réseau). Nous supposons que la comparaison sociale est assimilative, c'est-à-dire que l'on modifie son comportement afin de minimiser la différence/la distance entre lui ou elle et les autres (c'est-à-dire la "conformité"). Nous considérons le réseau exogène afin d'observer l'effet causal du réseau sur le comportement individuel, étant donné que les structures du réseau varient. Nous utilisons le cadre statique de l'équilibre de Nash pour examiner le résultat du jeu de la RCP sous forme d'hypothèses : chaque agent d'un réseau doit décider de l'effort à fournir pour extraire la ressource commune et en même temps prendre en compte ses comportements de voisinage direct afin de maximiser son utilité personnelle.

Nos résultats suggèrent que la comparaison sociale pourrait aider à façonner les comportements individuels de la manière dont elle contribue à promouvoir la conservation des ressources communes. Cependant, l'effet d'assimilation sur le comportement individuel de conservation dépend conditionnellement des différentes structures de réseau. En particulier, un réseau avec moins de connexions est meilleur que celui avec plus de connexions afin d'éviter le problème de la surexploitation. En outre, l'assimilation est suffisamment efficace dans les réseaux centralisés (comme un réseau en étoile) par rapport aux réseaux décentralisés (comme un cercle ou un réseau complet) pour inciter les individus à conserver la ressource commune.

En ce qui concerne l'implication politique, il est important que les décideurs politiques prennent soigneusement en compte les différents types de structures de réseau (c'est-à-dire la structure sociale) avant de mettre en œuvre toute politique (ou intervention) qui favorise la conservation des ressources en utilisant la comparaison assimilative. Une bonne façon de motiver la conservation de la RPC est de promouvoir l'assimilation dans le réseau centralisé. D'autre part, nous pouvons promouvoir la comparaison sociale dans le réseau décentralisé, mais il est important de conserver un effet d'assimilation relativement faible afin d'éviter la destruction de la RCP. Il est donc également essentiel de fournir des informations sur l'importance de la conservation des ressources aux acteurs clés du réseau (par exemple, un acteur central du réseau en étoile) afin d'encourager plus efficacement la conservation des ressources.

0.3.2 Chapitre 3 : Jeu de ressources communes sur le réseau endogène

Dans ce chapitre, nous étudions comment l'influence sociale dans le réseau endogène (c'est-à-dire les liens sont formés par les individus eux-mêmes) pourrait avoir un impact sur les comportements individuels dans un jeu de ressources communes. En outre, nous étudions comment les extractions de ressources individuelles sont liées à la connexion au réseau (c'est-à-dire à la fraction d'amis ou de voisins). En outre, à quel niveau d'influence sociale, de coût de la connexion et de taille du réseau, le système d'un jeu de RCP est localement stable (c'est-à-dire une extraction durable de la RCP).

Nous considérons dans notre modèle que les individus prendront en compte leurs comportements de voisinage (c'est-à-dire les comportements de voisinage direct de l'agent dans le réseau) avant de prendre leurs décisions. Dans cette étude, nous utilisons le cadre statique de l'équilibre de Nash pour examiner le résultat du jeu de RCP sous l'hypothèse d'une influence sociale (les agents sont influencés par leurs comportements de voisinage direct). Comme les efforts d'extraction et les connexions de réseau (c'est-à-dire le nombre total de voisins directs par rapport au nombre total d'agents ou la fraction d'amis ou de voisins) sont coûteux, les agents doivent décider de l'effort à fournir pour extraire la ressource et du nombre de liens de réseau auxquels se connecter afin de maximiser leur utilité personnelle. Il convient de noter qu'un agent i établira un lien vers j si et seulement si le coût de connexion est inférieur aux bénéfices tirés de l'établissement de connexion, de sorte que $\eta g_{ij} \leq \delta g_{ij}(\bar{x} - x_j)(\bar{x} - x_i)$, où η est le paramètre de coût de connexion; $g_{ij} = 1$ s'il existe un lien entre i et j; δ est le paramètre d'influence sociale; $\bar{x} = \bar{X}/N$ est la capacité d'effort d'extraction de l'individu avec des agents N et $\bar{X}$ le montant de la capacité des ressources; x_i et x_j sont l'effort d'extraction de i et j, respectivement. Ainsi, $\bar{x} - x$ est l'effort de conservation de l'agent.

Nous constatons que la présence de réseaux contribue à faire passer les comportements des agents de la substitution stratégique à la complémentarité stratégique. Et si la meilleure réponse est la complémentarité stratégique, l'incitation d'un agent entraînerait alors une réduction de l'extraction dans son réseau. En outre, il existe une relation négative entre la connexion au réseau et l'extraction d'un RCP par les agents. Cependant, il est nécessaire d'avoir soit un faible coût de connexion (c'est-à-dire un coût pour initier un lien avec un autre agent), soit une forte influence sociale pour encourager les agents à initier des liens avec d'autres et ainsi aider à promouvoir la conservation des ressources. De plus, en fonction des différents paramètres du coût de connexion, de l'influence sociale et de la taille du réseau, le jeu de la RCP existe un équilibre unique et localement stable. Nos résultats indiquent également que le système d'un jeu de RCP est localement instable s'il y a plus de six agents en concurrence pour l'extraction d'un RCP. Cela signifie que lorsque la taille du réseau augmente, nous sommes plus susceptibles d'assister à une destruction complète de la ressource commune (Saijo et al., 2017). Par conséquent, nous suggérons que les décideurs politiques ou les futures recherches prennent soigneusement en compte la taille des réseaux avant de concevoir un programme qui utilise l'influence sociale dans les réseaux pour encourager les individus à conserver les ressources communes.

Comme au début, nous supposons une situation dans laquelle les agents se soucient de leur effort de conservation du quartier, nos résultats soutiennent l'idée que la promotion de l'influence sociale dans les réseaux est bonne pour encourager la conservation des ressources car les agents seront plus susceptibles de conserver le bien commun tant qu'ils pourront bénéficier de leurs efforts de conservation du quartier. Cependant, pour encourager la connexion au réseau, il est nécessaire de maintenir un coût de connexion suffisamment bas et/ou une influence sociale élevée. Dans notre article, nous avons pu observer les changements de comportement des agents en fonction des paramètres de l'influence sociale. Par exemple, en présence d'une forte influence sociale, les agents seraient davantage incités à former des liens avec d'autres personnes, ce qui contribue à la conservation de la ressource commune. Cependant, une influence sociale forte ou faible par le biais d'un réseau dépend en réalité de la force de la norme sociale dans le réseau de l'agent, mais l'émergence d'une norme sociale est hors du champ de cette étude. Il est donc intéressant de l'étudier en profondeur dans une étude future car les normes sociales influencent le paramètre de l'influence sociale et déterminent ainsi s'il est bénéfique ou non pour un agent d'initier un lien avec ses voisins.

0.4 Le rôle des réseaux dans l'encouragement de l'agriculture biologique au Vietnam : Approches expérimentales

Partout dans le monde, nous nous sommes appuyés sur l'agriculture conventionnelle qui est une méthode largement utilisée dans l'agriculture industrielle pour produire la majorité des aliments que nous mangeons. Cependant, ce type de technique agricole est confronté à deux problèmes qui ont menacé son avenir. Dans l'agriculture conventionnelle, seuls 20 à 30 % des nutriments sont absorbés par les plantes, tandis que la partie restante des résidus chimiques se dissout rapidement dans l'eau, ce qui pollue les eaux souterraines (Liu et al., 2016). En fin de compte, les produits issus de l'agriculture conventionnelle ont perdu leur valeur alimentaire (Clark et al., 1998). Les aliments frelatés chimiquement pourraient sérieusement affecter la santé des consommateurs. Par exemple, le cancer, la maladie mortelle la plus courante aujourd'hui, a un lien direct avec l'adultération par les pesticides des aliments que nous consommons (Rodgers et al., 2018; Horrigan et al., 2002).

D'un point de vue économique, le coût de production de l'agriculture conventionnelle a rapidement augmenté car les agriculteurs dépendent de plus en plus de semences hybrides, d'engrais et de pesticides provenant de sources extérieures. Par conséquent, les bénéfices de l'agriculture conventionnelle deviennent moins rentables. C'est pourquoi les jeunes générations d'agriculteurs des pays en développement doivent chercher des débouchés dans les villes (Gartaula et al., 2012). Les gouvernements de nombreux pays en développement comme le Vietnam ont annoncé des prêts/subventions au lieu de s'attaquer à la véritable cause de la situation. Si la situation perdure, les pauvres risquent de devoir mourir de faim. Une agriculture plus durable est donc nécessaire pour résoudre cette situation compliquée (Huang et al., 2002; Horrigan et al., 2002).

L'agriculture biologique est un système de gestion agricole à large base. Elle améliore la santé des plantes et des autres créatures vivantes, et contribue ainsi à enrichir et à protéger la biodiversité. Les principales caractéristiques de l'agriculture biologique sont l'utilisation optimale et la conservation des intrants naturels disponibles localement, l'augmentation de la fertilité des sols sur une certaine période et la protection de la microflore du sol, etc. L'agriculture biologique vise à produire des aliments plus sains pour l'alimentation animale et à protéger la santé des consommateurs. L'autodépendance des intrants agricoles contribuera à accroître la rentabilité de l'exploitation. Si l'agriculture devient plus rentable, la migration de la population vers les villes diminuera alors. L'agriculture biologique peut donc apporter des solutions pour atténuer les effets négatifs sur l'environnement, ainsi que pour réduire les déséquilibres sociaux (Liu et al., 2016; Cui et al., 2018).

Ces dernières années, on observe un taux d'adoption relativement élevé de l'agriculture biologique dans certains pays développés en raison de la forte prise de conscience des problèmes de santé causés par la consommation d'aliments contaminés, des effets négatifs de la dégradation de l'environnement et surtout du soutien approprié des gouvernements et des organisations internationales comme l'Union européenne et la Fédération internationale des mouvements d'agriculture biologique (IFOAM) (Reisch et al., 2013)[1] Dans de nombreux pays en développement, l'agriculture conventionnelle contribue à fournir suffisamment de nourriture à la population et à générer des excédents pour l'exportation. Cependant, la méthode d'agriculture conventionnelle devient non durable, comme en témoignent la baisse de la productivité des cultures, la dégradation de l'environnement, la contamination chimique, etc. Dans d'autres pays en développement comme le Vietnam, la situation est encore pire : les agriculteurs utilisent les pesticides ouvertement et sans retenue.

Dans le contexte du Vietnam, selon le rapport du Ministère de l'Agriculture et du Développement Rural (MARD) (août 2018), le Vietnam a importé 79 millions de dollars de pesticides et de matières premières (environ 1 800 milliards de VND), ce qui porte la valeur des importations de pesticides et de matières premières au cours des huit premiers mois de 2017 à plus de 660 millions de dollars (plus de 15 000 milliards de VND), soit une augmentation de près de 47 % sur la même période de 2016. Les statistiques montrent que le Vietnam importe de plus en plus de pesticides et de matières premières et que l'importation de pesticides et de produits chimiques phytosanitaires a augmenté de façon

[1] IFOAM est apparue pour la première fois en France en 1972. Elle compte environ 600 organisations membres réparties dans 120 pays. L'IFOAM entreprend un large éventail d'activités liées à l'agriculture biologique, telles que l'échange d'informations et de connaissances entre ses membres.

continue au cours des dernières décennies en raison de l'expansion des surfaces cultivées et de la culture intensive de nombreuses plantes. Cependant, l'utilisation excessive de produits chimiques dans l'agriculture a eu de graves conséquences sur le sol et l'eau ainsi que sur la qualité des produits agricoles.

Selon la théorie du réseau social et économique, les individus sont toujours reliés à un réseau dans lequel ils interagissent et échangent des informations avec d'autres, comme un réseau d'amitié ou de voisinage (Jackson, 2010). Ces dernières années, grâce au réseau de relations sociales, l'information sur les médias sociaux peut se répandre incroyablement vite, non seulement au Vietnam mais dans le monde entier. Dans le domaine de l'agriculture, les agriculteurs peuvent non seulement se connecter aux réseaux en ligne des agriculteurs, mais surtout aux réseaux hors ligne, y compris les agriculteurs du voisinage, leurs amis et même les organisations agricoles dans lesquelles ils peuvent partager des informations, des idées et des réflexions sur les nouvelles méthodes agricoles. Toutefois, l'agriculture biologique se répand encore beaucoup plus lentement et on prévoit qu'il faudra des décennies pour qu'elle soit largement adoptée.

Plusieurs études ont montré qu'une contrainte potentielle du faible taux d'adoption est le manque d'informations crédibles sur l'agriculture biologique (Conley and Udry, 2010). Les agriculteurs manquent-ils d'informations sur la méthode d'agriculture biologique? Dans de nombreux cas, les agriculteurs savent personnellement qu'il est mauvais de mettre des produits chimiques dans les plantes, mais ils se soucient davantage de la productivité et sont prêts à utiliser de plus en plus de pesticides au fil du temps pour assurer une productivité élevée parce que la qualité des sols diminue avec le temps. Le gouvernement et les médias sociaux ont fourni des informations sur les effets négatifs de l'agriculture conventionnelle, la dégradation de l'environnement et la contamination des aliments, non seulement aux agriculteurs mais aussi aux consommateurs. Mais il ne semble pas suffisant d'encourager les agriculteurs à se tourner vers l'agriculture biologique. Par exemple, un agriculteur a déclaré aux médias sociaux que "nous savons que l'utilisation de pesticides est néfaste pour les consommateurs et l'environnement, mais ne pas utiliser de pesticides nocifs signifie une tolérance aux risques comme le débordement des mauvaises herbes, l'attaque de l'escargot jaune, etc.". Il est donc important d'étudier comment encourager efficacement les agriculteurs à s'orienter vers une agriculture plus durable.

Afin de répondre à cette question, nous étudions comment le rôle des réseaux pourrait encourager les agriculteurs à se tourner vers l'agriculture biologique en utilisant des données expérimentales dans le nord du Vietnam. En particulier, dans le chapitre 4, nous utilisons les données d'une expérience contextualisée de laboratoire sur le terrain pour étudier le rôle des réseaux, de la comparaison sociale et du coup de pouce informationnel dans la promotion des décisions d'investissement des agriculteurs dans l'agriculture biologique. Le rôle des réseaux et du leadership dans l'encouragement de l'agriculture biologique est étudié au chapitre 5 à l'aide d'une expérience de choix discret.

0.4.1 Chapitre 4 : Les moteurs de l'agriculture biologique : Preuves d'une expérience contextualisée de laboratoire sur le terrain du rôle de la comparaison sociale et du coup de pouce à l'information dans les réseaux au Vietnam

Ce chapitre examine les réactions des agriculteurs aux décisions d'investissement dans l'agriculture biologique en utilisant différents traitements expérimentaux, notamment les structures de réseau, la comparaison sociale et le coup de pouce à l'information. Dans cette étude, nous examinons pourquoi les petits exploitants agricoles sont réticents à adopter des pratiques pro-environnementales, notamment l'agriculture biologique, au Vietnam. Nous avons mené 22 sessions expérimentales en août 2019 dans quatre provinces différentes du nord du Vietnam afin de mieux comprendre les incitations sociales et le rôle des réseaux sur les décisions des agriculteurs d'investir dans l'agriculture biologique. Au total, 220 petits exploitants agricoles ont participé à une expérience sur le terrain en utilisant l'IPad.

L'expérience a été mise en œuvre avec 11 scénarios expérimentaux, résultant de la combinaison des types de structures de réseau, de la présence d'une comparaison sociale et du traitement des informations. L'expérience comportait quatre parties. Dans la première partie, nous avons procédé à un tirage au sort pour déterminer la sensibilité des agriculteurs à l'aversion au risque. Le montant d'argent non investi a été utilisé comme indicateur relatif de l'aversion au risque. Dans la deuxième partie, les agriculteurs ont participé à un simple jeu d'investissement biologique avec un réseau vide, sans comparaison sociale ni coup de pouce informationnel dans un jeu répété sur 5 périodes. Dans la troisième partie, les expériences de réseau ont été menées. Notre expérience comporte deux variables de traitement principales : la comparaison sociale et la comparaison sociale combinée avec le coup de pouce à l'information. Le traitement de contrôle est le "pas de traitement" avec soit une "comparaison sociale" soit un "coup de pouce à l'information". Nous testons ces deux traitements et le contrôle dans quatre types différents de structure de réseau (réseau vide, cercle, étoile et réseaux complets). La comparaison sociale est une information sur l'investissement moyen de l'ensemble du groupe après chaque cycle, donnée à tous les agriculteurs du réseau. Dans le traitement "comparaison sociale combinée avec le coup de pouce de l'information", chaque sujet a reçu des informations supplémentaires sur le niveau d'investissement socialement optimal au début de chaque cycle. La troisième partie de l'expérience a été répétée dix fois. Dans la quatrième partie, des informations qualitatives et quantitatives (par exemple, âge, sexe, taille de l'exploitation, taille du ménage, type de résidence, revenu individuel et du ménage, santé, etc.) sont recueillies.

Nous avons également obtenu des informations sur un certain nombre de préoccupations environnementales par le biais de 15 questionnaires du NEP afin de nous aider à identifier les perceptions individuelles à l'égard de l'environnement (Dunlap et al., 2000).

Nous constatons que le réseau joue un rôle clé pour encourager l'adoption de l'agriculture biologique. Toutefois, cet effet diffère selon le type de réseau (cercle, étoile ou réseau complet), ce qui indique que le rôle des individus et le nombre de connexions individuelles sont importants. Ce résultat est conforme à la littérature selon laquelle les réseaux ayant plus de connexions sont meilleurs que les réseaux ayant moins de connexions pour faciliter la coordination (McCubbins et al., 2009). Ce résultat suggère également que l'approche fondée sur les réseaux peut être considérée comme une méthode rentable pour les décideurs politiques afin d'inciter les agriculteurs à adopter un comportement positif à l'égard de l'agriculture biologique (Beaman and Dillon, 2018). Deuxièmement, notre analyse révèle également que le traitement "comparaison sociale combinée à l'encouragement à l'information" a un impact positif sur les décisions des agriculteurs, quels que soient les types de réseaux. Le traitement "comparaison sociale" donne des résultats moins tranchés car il n'y a un effet positif et significatif que dans le réseau du cercle. Enfin, certaines des variables de contrôle (âge, sexe, santé, appartenance à une association d'agriculteurs, intérêt pour l'agriculture biologique) sont significatives pour expliquer la décision d'investir dans l'agriculture biologique. Par exemple, les agricultrices sont moins susceptibles d'investir dans l'agriculture biologique que les hommes. Les agriculteurs plus âgés semblent investir davantage que les plus jeunes dans l'agriculture biologique. D'autres variables comme le NEP, le niveau d'éducation, l'aversion au risque, le revenu, la taille de l'exploitation n'ont pas d'impact significatif sur les décisions d'investissement des agriculteurs.

Selon ces conclusions, notre étude suggère que les décideurs politiques peuvent s'appuyer sur les structures de réseaux d'agriculteurs et sur la comparaison sociale ainsi que sur le coup de pouce de l'information pour améliorer les décisions des agriculteurs en vue d'adopter une agriculture plus durable au Vietnam. Nos résultats suggèrent également qu'il existe une possibilité d'effet d'entassement, car l'effet de la comparaison sociale et de l'incitation à l'information dépasse l'effet de la comparaison sociale. Il est intéressant pour une étude plus approfondie d'examiner le mécanisme sous-jacent de l'effet d'éviction et de l'effet d'entassement dans les poussées sociales (poussées de comparaison et d'information), car elles ont une implication importante dans la garantie d'une agriculture durable.

0.4.2 Chapitre 5 : Préférences des agriculteurs pour l'agriculture biologique : Preuves d'une expérience de choix dans le nord du Vietnam

Dans ce chapitre, nous étudions les préférences des agriculteurs pour l'adoption de l'agriculture biologique en utilisant l'expérience du choix discret avec au total 586 agriculteurs du nord du Vietnam. L'expérience de choix discret a été menée pour mesurer comment divers facteurs liés au marché (notamment le contrat de vente et le logo biologique avec code de traçabilité) et facteurs non liés au marché (notamment la formation et les conseils techniques, les dirigeants et les voisins du village pratiquant l'agriculture biologique) pouvaient influencer les décisions des agriculteurs en matière d'adoption de l'agriculture biologique. L'expérience de choix a présenté aux répondants des scénarios à choix multiples. Chaque fois qu'il s'agissait d'une situation hypothétique, les agriculteurs étaient invités à choisir entre deux alternatives d'"agriculture biologique" non étiquetées (options biologiques 1 et 2) et une alternative de "statu quo". Le "statu quo" est choisi si les agriculteurs décident de ne choisir ni l'option biologique 1 ni l'option biologique 2. Les deux options "biologiques" sont décrites par un certain nombre de caractéristiques différentes.

L'expérience vise tout d'abord à analyser les préférences des agriculteurs pour l'agriculture biologique, présentées par le premier attribut "Formation et conseils techniques". Il s'agit de leçons pratiques dispensées gratuitement aux agriculteurs afin d'améliorer leurs connaissances sur l'agriculture biologique, ainsi que sur les pratiques agricoles biologiques. En plus de la "formation", les agriculteurs disposent de techniciens ou de spécialistes dans leur région pour leur conseiller l'agriculture biologique. Deuxièmement, la sensibilité aux différents contrats de vente dans l'agriculture biologique, présentée par l'attribut "Contrat de vente". Celui-ci est défini comme un contrat de vente entre les agriculteurs et les acheteurs. Les acheteurs peuvent être des détaillants (supermarchés, entreprises), des coopératives ou des consommateurs directs. Nous avons deux types de contrats : un contrat avec des prix fixes garantis et un contrat avec des prix flexibles sur des périodes de cinq ans. Troisièmement, l'expérience comprend également l'attribut "traçabilité", qui est un code de traçabilité accompagnant le logo biologique sur chaque produit biologique. Cela indique que les produits des agriculteurs ont déjà été soumis à un contrôle de qualité strict et que les consommateurs peuvent donc facilement distinguer les produits biologiques des produits non biologiques. Quatrièmement, les deux derniers attributs "Voisin" et "Leader" indiquent la présence dans le village d'agriculteurs et de leaders du voisinage pratiquant l'agriculture biologique. Enfin, l'attribut "coût" est un élément majeur utilisé pour saisir la volonté des agriculteurs de payer pour l'agriculture biologique. Le coût comprend 6 niveaux qui sont en termes de pourcentage d'augmentation du coût de production, 0%, 10%, 30%, 60%, 100%, 150%. Le coût supplémentaire par unité est utilisé pour mieux cerner la volonté de payer des agriculteurs, car ceux-ci produisent souvent des produits agricoles différents (c'est-à-dire une diversification des produits). Une autre raison pour laquelle le coût relatif est appliqué, est que les agriculteurs qui produisent les mêmes produits agricoles mais dans des zones rurales différentes peuvent également avoir des coûts de production très différents.

Nos résultats suggèrent que le "contrat de vente" avec des prix flexibles ou garantis est un élément majeur qui explique la volonté des agriculteurs d'adopter l'agriculture biologique. En effet, l'engagement sur le prix des produits agricoles est considéré par les agriculteurs comme une opportunité de soutenir l'agriculture biologique. Ce résultat est conforme à la littérature sur "l'agriculture contractuelle" (c'est-à-dire que l'acheteur fournit aux agriculteurs un crédit, des conseils techniques, un service de marché, etc. En contrepartie, les agriculteurs produisent certaines quantités et certaines qualités de produits et les vendent à l'acheteur), ce qui indique qu'un tel arrangement pourrait contribuer positivement au revenu des agriculteurs en particulier et à la croissance et à la réduction de la pauvreté en général (Weiss and Khan, 2006; Bolwig et al., 2009).

En outre, l'attribut "formation et conseil technique" est également un facteur important qui peut être utilisé pour motiver les agriculteurs à se tourner vers l'agriculture biologique. En effet, les petits exploitants ont souvent plus de difficultés (par exemple, trop coûteux ou manque d'informations et de connaissances) à accéder aux pratiques de l'agriculture biologique que les grands exploitants. Il est donc nécessaire de disposer de conseillers locaux et de formations/leçons intensives pour les motiver à se tourner vers l'agriculture biologique. Ce résultat est également conforme aux études existantes qui ont suggéré que la connaissance technique des pratiques de l'agriculture biologique est un obstacle important à la transition vers l'agriculture biologique (Brock and Barham, 2013; Dimitri and Baron, 2019).

Enfin, l'attribut "voisin", qui mesure la présence ou non de voisins dans le village des agriculteurs pratiquant l'agriculture biologique, est également important pour encourager les agriculteurs à changer leur méthode d'exploitation en faveur de l'agriculture biologique. Cela suggère que les agriculteurs semblent être influencés par leurs voisins dans l'adoption de l'agriculture biologique. En effet, les agriculteurs du voisinage sont parfois une source précieuse d'informations et de connaissances pour les agriculteurs, surtout lorsque les agriculteurs de la zone rurale ont souvent de bonnes relations avec leurs voisins. Par conséquent, le rôle des réseaux (c'est-à-dire la connexion de voisinage) est également important et doit être pris en compte par les décideurs politiques ou les futures recherches.

0.5 Conclusion

En conclusion, cette thèse contribue à la littérature existante en étudiant en profondeur les impacts des incitations sociales (y compris les comparaisons sociales et les informations) dans différents réseaux (y compris les réseaux exogènes et endogènes) de manière théorique et empirique. Les résultats de cette thèse suggèrent que la promotion de la connexion aux réseaux et des incitations sociales (par exemple, l'influence sociale interne qui motive les gens à changer leurs perceptions et leurs attitudes) pourrait contribuer à encourager le comportement pro-environnemental (voir le chapitre 1). Ce résultat est confirmé par les résultats de notre expérience de choix discret (voir chapitre 5), puisque les agriculteurs qui choisissent l'agriculture biologique comme alternative sont prêts à payer pour que des agriculteurs de leur quartier pratiquent l'agriculture biologique. En effet, les agriculteurs du voisinage sont des sources précieuses d'informations, de connaissances et de motivation qui pourraient aider les agriculteurs à se tourner vers l'agriculture biologique. Nos résultats du jeu de RPC en réseau endogène (voir chapitre 3) suggèrent également qu'il est important de promouvoir un coût de mise en relation suffisamment bas (c'est-à-dire un coût que l'on doit payer pour initier une mise en relation avec d'autres) pour inciter les individus à se mettre en relation avec d'autres (c'est-à-dire promouvoir la mise en réseau) et contribue ainsi à encourager la conservation des ressources du pool commun. Par conséquent, la promotion de la socialisation ou de la connexion en réseau est essentielle pour motiver les individus à se comporter de manière positive envers l'environnement.

De plus, la mise en place d'incitations sociales (par exemple, des comparaisons sociales et des informations) dans les réseaux pourrait contribuer à promouvoir un comportement pro-environnemental. Toutefois, la structure des réseaux est importante et doit être soigneusement prise en compte, car nos résultats au chapitre 2 indiquent que la comparaison sociale pourrait avoir des effets différents sur les comportements individuels selon les types de réseaux (par exemple, réseau en cercle, en étoile ou complet). Plus précisément, en présence d'assimilation dans la comparaison sociale (par exemple, les individus comparent leurs comportements à ceux de leurs voisins directs), il est plus efficace de motiver les agents des réseaux centralisés (comme un réseau en étoile) à conserver la ressource commune que les réseaux décentralisés (comme un cercle ou un réseau complet). Nos résultats de l'expérience contextualisée de laboratoire sur le terrain (voir chapitre 4) suggèrent également que le traitement de comparaison sociale (c'est-à-dire que les individus ont reçu des informations sur l'investissement moyen du groupe dans l'agriculture biologique) est suffisamment efficace dans un réseau en cercle (c'est-à-dire un réseau décentralisé avec moins de connexions) pour encourager les agriculteurs à se tourner vers l'agriculture biologique que dans un réseau en étoile et complet (c'est-à-dire un réseau décentralisé avec plus de connexions). Il est donc essentiel de prendre soigneusement en compte les structures du réseau avant de promouvoir les incitations sociales (par exemple, les comparaisons sociales et les informations) pour motiver efficacement les individus à adopter un comportement positif vis-à-vis de l'environnement.

Cependant, en réalité, il est très difficile pour les décideurs politiques ou les individus eux-mêmes d'observer pleinement la structure réelle du réseau ainsi que chaque comportement ou action individuelle dans le réseau. Cela signifie que fournir des incitations sociales comme la comparaison sociale (par exemple, des informations sur le comportement moyen du groupe) pourrait être un moyen efficace de promouvoir le comportement pro-environnemental. En outre, il est toujours plus facile d'observer les comportements/actions d'un ou deux agents les plus importants du réseau que d'observer pleinement les comportements de tous les agents. Ainsi, une autre solution consiste à motiver le rôle de l'agent central (c'est-à-dire un dirigeant ou une personne influente, etc.) à promouvoir le comportement pro-environnemental, car nous observons que la motivation du rôle des agents centraux dans le réseau en étoile pourrait contribuer à promouvoir de manière significative la conservation des ressources communes (voir chapitre 2).

Bibliography

Allcott, H. and T. Rogers (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review 104*(10), 3003–3037.

Arrow, K. (1970). Political and economic evaluation of social effects and externalities. In *The Analysis of Public Output*, Chapter 1, pp. 1–30. National Bureau of Economic Research.

Ashenmiller, B. (2011). The effect of bottle laws on income: New empirical results. *American Economic Review 101*(3), 60–64.

Barnes, M. L., J. Lynham, K. Kalberg, and P. Leung (2016). Social networks and environmental outcomes. *Proceedings of the National Academy of Sciences 113*(23), 6466–6471.

Baumol, W. J. (1972). On taxation and the control of externalities. *The American Economic Review 62*(3), 307–322.

Beaman, L. and A. Dillon (2018). Diffusion of agricultural information within social networks: Evidence on gender inequalities from Mali. *Journal of Development Economics 133*, 147–161.

Bjørner, T. B., L. G. Hansen, and C. S. Russell (2004). Environmental labeling and consumers' choice—an empirical analysis of the effect of the Nordic Swan. *Journal of Environmental Economics and Management 47*(3), 411–434.

Bolton, G. E. and A. Ockenfels (2000). ERC: A theory of equity, reciprocity, and competition. *American Economic Review 90*(1), 166–193.

Bolwig, S., P. Gibbon, and S. Jones (2009). The economics of smallholder organic contract farming in tropical Africa. *World Development 37*(6), 1094–1104.

Bowles, S. and H. Gintis (2011). *A Cooperative Species: Human Reciprocity and Its Evolution*. Princeton University Press.

Bramoullé, Y., R. Kranton, et al. (2007). Public goods in networks. *Journal of Economic Theory 135*(1), 478–494.

Brock, C. C. and B. L. Barham (2013). 'Milk is mil': Organic dairy adoption decisions and bounded rationality. *Sustainability 5*(12), 5416–5441.

Bromley, D. W. and M. M. Cernea (1989). *The Management of Common Property Natural Resources: Some Conceptual and Operational Fallacies*. World Bank Publications.

Brülisauer, M., L. Goette, Z. Jiang, J. Schmitz, and R. Schubert (2020). Appliance-specific feedback and social comparisons: Evidence from a field experiment on energy conservation. *Energy Policy 145*, 111742.

Cárdenas, J. C., C. Mantilla, and R. Sethi (2015). Stable sampling equilibrium in common pool resource games. *Games 6*(3), 299–317.

Centola, D. (2010). The spread of behavior in an online social network experiment. *Science 329*(5996), 1194–1197.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: A selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Cho, S. and H. Kang (2017). Putting behavior into context: Exploring the contours of social capital influences on environmental behavior. *Environment & Behavior 49*(3), 283–313.

Cho, Y. N., A. Thyroff, M. I. Rapert, S. Y. Park, and H. J. Lee (2013). To be or not to be green: Exploring individualism and collectivism as antecedents of environmental behavior. *Journal of Business Research 66*(8), 1052–1059.

Cialdini, R. B. (1987). *Influence*, Volume 3. A. Michel Port Harcourt.

Clark, C. F., M. J. Kotchen, and M. R. Moore (2003). Internal and external influences on pro-environmental behavior: Participation in a green electricity program. *Journal of Environmental Psychology 23*(3), 237–246.

Clark, M. S., W. R. Horwath, C. Shennan, and K. M. Scow (1998). Changes in soil chemical properties resulting from organic and low-input farming practices. *Agronomy Journal 90*, 662–671.

Conley, T. G. and C. R. Udry (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review 100*(1), 35–69.

Cui, Z., H. Zhang, X. Chen, C. Zhang, W. Ma, C. Huang, W. Zhang, G. Mi, Y. Miao, X. Li, et al. (2018). Pursuing sustainable productivity with millions of smallholder farmers. *Nature 555*, 363–366.

Diederich, J. and T. Goeschl (2014). Willingness to pay for voluntary climate action and its determinants: Field-experimental evidence. *Environmental and Resource Economics 57*(3), 405–429.

Dimitri, C. and H. Baron (2019). Private sector support of the farmer transition to certified organic production systems. *Organic Agriculture*, 1–16.

Dufwenberg, M., P. Heidhues, G. Kirchsteiger, F. Riedel, and J. Sobel (2011). Other-regarding preferences in general equilibrium. *The Review of Economic Studies 78*(2), 613–639.

Dunlap, R. E., K. D. Van Liere, A. G. Mertig, and R. E. Jones (2000). New trends in measuring environmental attitudes: Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues 56*(3), 425–442.

Espinosa-Goded, M., J. Barreiro-Hurlé, and E. Ruto (2010). What do farmers want from agri-environmental scheme design? A choice experiment approach. *Journal of Agricultural Economics 61*(2), 259–273.

Frey, B. S. and S. Meier (2004). Social comparisons and pro-social behavior: Testing "conditional cooperation" in a field experiment. *American Economic Review 94*(5), 1717–1722.

Gartaula, H., A. Niehof, and L. Visser (2012). Shifting perceptions of food security and land in the context of labour out-migration in rural Nepal. *Food Security 4*(2), 181–194.

Gould, R. K., N. M. Ardoin, J. M. Thomsen, and N. Wyman Roth (2019). Exploring connections between environmental learning and behavior through four everyday-life case studies. *Environmental Education Research 25*(3), 314–340.

Gouu, R. V. (1993). Collective action and network structure. *American Sociological Review 58*(2), 182–196.

Grund, T., C. Waloszek, and D. Helbing (2013). How natural selection can create both self- and other-regarding preferences, and networked minds. *Scientific Reports 3*, 1480–1480.

Hardin, G. (1968). The tragedy of the commons. *Science 162*(3859), 1243–1248.

Horrigan, L., R. S. Lawrence, and P. Walker (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives 110*(5), 445–56.

Huang, J., C. Pray, and S. Rozelle (2002). Enhancing the crops to feed the poor. *Nature 418*, 678–684.

Jackson, M. O. (2010). *Social and Economic Networks*. Princeton university press.

Jackson, M. O., B. W. Rogers, and Y. Zenou (2017). The economic consequences of social-network structure. *Journal of Economic Literature 55*(1), 49–95.

Klooster, D. (2005). Environmental certification of forests: The evolution of environmental governance in a commodity network. *Journal of Rural Studies 21*(4), 403–417.

Kollmuss, A. and J. Agyeman (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research 8*(3), 239–260.

Krawczyk, M., A. Bartczak, N. Hanley, and A. Stenger (2016). Buying spatially-coordinated ecosystem services: An experiment on the role of auction format and communication. *Ecological Economics 124*, 36–48.

Kühnen, U. and B. Hannover (2000). Assimilation and contrast in social comparisons as a consequence of self-construal activation. *European Journal of Social Psychology 30*(6), 799–811.

Lazaric, N., F. Le Guel, J. Belin, V. Oltra, S. Lavaud, and A. Douai (2019). Determinants of sustainable consumption in france: the importance of social influence and environmental values. *Journal of Evolutionary Economics*, 1–30.

Lefebvre, M. and A. Stenger (2020). Short-& long-term effects of monetary and non-monetary incentives to cooperate in public good games: An experiment. *Plos One 15*(1), e0227360.

Liu, H., J. Meng, W. Bo, D. Cheng, Y. Li, L. Guo, C. Li, Y. Zheng, M. Liu, T. Ning, et al. (2016). Biodiversity management of organic farming enhances agricultural sustainability. *Scientific reports 6*(1), 1–8.

Mantilla, C. (2015). Communication networks in common-pool resource games: Field experimental evidence. *Journal of Economic Behavior & Organization 118*, 215–226.

Marsden, P. V. and N. Lin (1982). *Social Structure and Network Analysis*. Sage Beverly Hills.

McCubbins, M. D., R. Paturi, and N. Weller (2009). Connected coordination: Network structure and group coordination. *American Politics Research 37*(5), 899–920.

McPherson, M., L. Smith-Lovin, and J. M. Cook (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology 27*(1), 415–444.

Mekonnen, A., R. Bluffstone, et al. (2017). Does community forest collective action promote private tree planting? Evidence from Ethiopia. *International Business Research 10*(5), 86–106.

Nisbet, E. K., J. M. Zelenski, and S. A. Murphy (2009). The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior 41*(5), 715–740.

Nolan, J. M., P. W. Schultz, R. B. Cialdini, N. J. Goldstein, and V. Griskevicius (2008). Normative social influence is underdetected. *Personality and Social Psychology Bulletin 34*(7), 913–923.

O'Shea, L. (2002). An economic approach to reducing water pollution: Point and diffuse sources. *Science of the Total Environment 282*, 49–63.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Political Economy of Institutions and Decisions. Cambridge University Press.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change 20*(4), 550–557.

Ostrom, E., R. Gardner, and J. Walker (1994). *Rules, Games, and Common-Pool Resources*. University of Michigan Press.

Patacchini, E. and Y. Zenou (2012). Juvenile delinquency and conformism. *The Journal of Law, Economics, & Organization 28*(1), 1–31.

Pearce, D. W. and R. K. Turner (1990). *Economics of Natural Resources and the Environment*. Johns Hopkins University Press.

Pelletier, L. G., S. Dion, K. Tuson, and I. Green-Demers (1999). Why do people fail to adopt environmental protective behaviors? Toward a taxonomy of environmental amotivation. *Journal of Applied Social Psychology 29*(12), 2481–2504.

Polman, N. and L. Slangen (2008). Institutional design of agri-environmental contracts in the European Union: The role of trust and social capital. *NJAS - Wageningen Journal of Life Sciences 55*(4), 413–430.

Rametsteiner, E. and M. Simula (2003). Forest certification-an instrument to promote sustainable forest management? *Journal of Environmental Management 67*(1), 87–98.

Reisch, L., U. Eberle, and S. Lorek (2013). Sustainable food consumption: An overview of contemporary issues and policies. *Sustainability: Science, Practice and Policy 9*(2), 7–25.

Robert, N. and A. Stenger (2013). Can payments solve the problem of undersupply of ecosystem services? *Forest Policy and Economics 35*, 83–91.

Rodgers, K. M., J. O. Udesky, R. A. Rudel, and J. G. Brody (2018). Environmental chemicals and breast cancer: An updated review of epidemiological literature informed by biological mechanisms. *Environmental Research 160*, 152–182.

Saijo, T., J. Feng, and Y. Kobayashi (2017). Common-pool resources are intrinsically unstable. *International Journal of the Commons 11*(2), 597–620.

Santos, F. C., M. D. Santos, and J. M. Pacheco (2008). Social diversity promotes the emergence of cooperation in public goods games. *Nature 454*(7201), 213–216.

Schmalensee, R. and R. N. Stavins (2017). The design of environmental markets: What have we learned from experience with cap and trade? *Oxford Review of Economic Policy 33*(4), 572–588.

Schubert, C. (2017). Green nudges: Do they work? Are they ethical? *Ecological Economics 132*, 329–342.

Schwartz, D., G. Loewenstein, and L. Agüero-Gaete (2020). Encouraging pro-environmental behaviour through green identity labelling. *Nature Sustainability*, 1–7.

Scott, J. (1988). Social network analysis. *Sociology 22*(1), 109–127.

Steg, L. and C. Vlek (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology 29*(3), 309–317.

Thomas, C. and V. Sharp (2013). Understanding the normalisation of recycling behaviour and its implications for other pro-environmental behaviours: A review of social norms and recycling. *Resources, Conservation and Recycling 79*, 11–20.

Van Laerhoven, F. (2010). Governing community forests and the challenge of solving two-level collective action dilemmas-a large-N perspective. *Global Environmental Change 20*(3), 539–546.

Weiss, J. and H. Khan (2006). *Poverty Strategies in Asia: A Growth Plus Approach*. Edward Elgar Publishing.

Chapter 0

Introduction

0.1 Motivation of the dissertation

Understanding individual behavior is not only important in sociology, psychology and business but also a basic objective of economists and environmentalists. The fundamental issue faced by both economist and environmentalist scholars is how to adequately promote "*pro-environmental behavior*" (e.g., how to effectively motivate people to either protect their local surrounding environment or to fight against global climate change). "*Pro-environmental behavior*" refers to behavior that could either benefit the environment or harm the environment but as little as possible (Steg and Vlek, 2009). In this sense, a variety of theoretical models and empirical works have been developed to study the impact of monetary as well as non-monetary incentives (i.e., social incentives) on individual pro-environmental behaviors (Kollmuss and Agyeman, 2002; Clark et al., 2003; Allcott and Rogers, 2014; Diederich and Goeschl, 2014; Lazaric et al., 2019; Schwartz et al., 2020). Numerous studies have proved that both monetary and social incentives could have significant impacts on individual pro-environmental behavior. For instance, giving payments (e.g., payments for ecosystem services, agri-environmental scheme, etc.) (Espinosa-Goded et al., 2010; Robert and Stenger, 2013; Krawczyk et al., 2016), social feedback (e.g., household consumption report) (Allcott and Rogers, 2014; Brülisauer et al., 2020) or nudges (Schubert, 2017; Lefebvre and Stenger, 2020) could help to encourage people to protect the environment by consuming less energy, water or doing more recycling, etc..

However, focusing on either monetary or social incentives when addressing environmental issues may raise several problems: for example, an individual who takes an action to alleviate his or her sense of obligation to help to improve environmental quality (e.g., driving less or planting more trees) may then not take any further actions when he or she realizes that others do not cooperate. This could be defined as a single action bias. Furthermore, for most environmental issues (e.g., biodiversity, deforestation, energy, etc.), it is necessary to have many individuals but most often within the same area who adhere to a conservation program in order to reach a necessary threshold (proportion of individuals in the network) above which a positive program effect can arise. Thus, several studies suggest that network factors can also be used to promote “collective pro-environmental behaviors", which are behaviors taken together by a group of individuals and including society as a whole (i.e., collective actions) to achieve an environmental target (Gouu, 1993; Van Laerhoven, 2010).

In recent years, the concept of “social and economic network" (e.g., how network structure affects behaviors) has been developed and captured much more attention of policymakers as well as research scholars (Jackson, 2010; Jackson et al., 2017). Note that network structure or social structure is a structure made up of social actors (e.g., individuals or organizations) and social links/ties (i.e., interactions or connections between actors) (Marsden and Lin, 1982; Scott, 1988). For instance, in their studies, the authors have shown that individuals’ decisions in performing a behavior/an action could therefore be collectively influenced by others’ behaviors in a network (i.e., collective behaviors) (Bramoullé et al., 2007; Jackson, 2010). Moreover, several studies, which are not related to networks, also indicated that instead of making independent decisions, individuals often considers utility of others and take them into his or her decision making process (i.e., “other-regarding" preferences) (Bolton and Ockenfels, 2000; Grund et al., 2013). Some other studies also suggested that humans truly care about others, especially when they are linked to others in a network (e.g., a network of friends, colleagues, neighbors, etc.) (Dufwenberg et al., 2011; Grund et al., 2013). Consequently, the role of networks could be seen as an important factor/determinant, which can be used to motivate individuals to behave positively towards the environmental (i.e., pro-environmental behaviors).

In recent years, several studies have been conducted to investigate the role of networks in promoting pro-environmental behaviors: how social interaction in networks (i.e., ones interact with others in a network) could affect farmers’ behaviors on restriction of intensive practices (Polman and Slangen, 2008); how information sharing and environmental messages through network could encourage resource conservation (Mantilla, 2015; Barnes et al., 2016; Mekonnen et al., 2017); and whether individuals who care about each other (i.e., other-regarding preferences) could influence individuals’ intentions to participate in environmental groups or not (Cho et al., 2013; Cho and Kang, 2017). All these existing literature suggested that networks could therefore play an important role in incentivizing individuals to behave positively towards environmental sustainability. Although, several researches have been conducted to investigate the role of networks on individuals’ pro-environmental behaviors, there are still many questions that existing literature has left open. In other words, while a majority of existing studies focused on how social interaction and information sharing through network could motivate individual behavioral change, a handful of researches studies how providing social incentives (e.g., social comparison, information nudges, etc.) to individuals in different network structures could effectively incentivize their pro-environmental behaviors. Therefore, the primary objective of this dissertation is to provide insight into impacts of social incentives in networks on individual pro-environmental behaviors.

Moreover, while some studies have already focused on changes in environmental outcome related to changes in network structure, there has been little attention to the impacts of individual pro-environmental behaviors on the emergence of networks. The theory of "principle of homophily" indicated that individuals who behave similarly tend to live in a same form of society because of the social selection (i.e., individuals with similar characteristics such as, same ethnicity, gender, race, age, and social status) (McPherson et al., 2001). As a result, providing social incentives through networks could make individuals who are not (or already) in the community before may be influenced by others and decide to move in (or out) of the network or community. Therefore, if individual behavior changes also have an impact on the emergence of networks, then it is important to study how social incentives in both exogenous network (i.e., network structure is given) and endogenous network (i.e., network structure is not given and individuals can decide who they will form a link with) could help to promote and to sustain the pro-environmental behavior.

To sum up, this dissertation aims to contribute to existing literature by deeply investigating the impacts of social incentives in networks and its impact on pro-environmental behaviors, including resource conservation and investment in organic farming. In particular, we focus on the analysis of the impacts of social incentives in different exogenous networks (e.g., star, circle and complete network) and endogenous network (i.e., network structure is not given) in both theoretical and empirical ways. We develop theoretical models to study individual behaviors in a common pool resource game that takes both exogenous network (i.e., network is given or formed by the central social planner) and endogenous network (i.e., network is formed by individuals themselves) into account. We also conduct a contextualized *lab-in-the-field* and discrete choice experiment to study how promoting networks as well as providing different types of social incentives (e.g., social comparison and information nudges) in different types of networks (e.g., circle, star, complete network, etc.) could impact individual behavior in adopting organic farming. More specifically, these questions are studied in five following Chapters.

- Chapter 1 provides insights into the strength and relevance of several social incentive factors in promoting pro-environmental behaviors. In particular, we used a meta-analysis to access the effectiveness of seven groups of social incentives: internal and external social influence, network factors including network size, network connection and leadership and trust including trust in institutions and trust in others, that can promote pro-environmental behaviors.

- Chapter 2 theoretically studies the role of social comparison in different network structures in encouraging individual conservation behavior in a common pool resource (CPR) game. More precisely, we investigate how assimilation in social comparison (i.e., changing behavior in order to fit in with a group) in different network structures including an empty network, star, circle or complete network) could help to promote common pool resource conservation.
- Chapter 3 theoretically investigates how social influence (i.e., neighborhood resource conservation) in the situation of endogenous network (i.e., network is formed by individuals themselves) could impact individual behaviors in a common pool resource game. In our model, agents have to simultaneously choose their level of effort in extracting the resource and the number of neighbors to link with in order to maximize their payoffs. Thus, since the network is endogenous, it is interesting to observe that at which level of social influence, cost of linking and network size, the system of a CPR game (i.e., the equilibrium of extraction and network connection) will be locally stable (sustainable conservation) and unstable (destruction of CPR).
- Chapter 4 explores the role of social comparison (i.e., information about the average group organic investment) and information nudge (i.e., information about the socially optimal investment of their neighbors and themselves) in different network structures (e.g., empty network, star, circle and complete network) on farmers' decisions in organic farming investment via a contextualized lab-in-the-field experiment in Northern Vietnam.
- Chapter 5 studies farmers' preferences toward organic farming using discrete choice experiment with farmers in Northern Vietnam. In particular, we measure how various market factors (including sale contract and logo with traceable code) and nonmarket factors (including role of networks (i.e., neighborhood farmer doing organic farming), training and technical advice, role of leader (i.e., formal or/and informal leaders doing organic farming)) could influence farmers' decisions in adopting organic farming.

0.2 Social incentives in promoting pro-environmental behaviors

Incentives are used to motivate individuals to behave in a socially desirable sense. From the environmental economic point of view, there are two different types of incentive approaches: monetary and non-monetary incentives. For instance, the Pigouvian tax is a monetary incentive (i.e., economic incentive), developed by Pigou in 1920, which is used to encourage polluters to reduce their pollution emissions (Baumol, 1972). Similarly, the cap-and-trade scheme, is also a monetary incentive, which is used to incentivize polluting actors to reduce their emissions by providing firms cap/initial allowance on greenhouse gas emission as well as allowing them to buy or sell their allowances. Existing literature suggested that monetary incentives could give individuals or private sectors a strong incentive to save money by cutting their emissions (Schmalensee and Stavins, 2017).

However, in reality, the implementations of the monetary incentives also face many difficulties. The first issue, encountered by the economists in development of various instruments and regulations for pollution, is information constraint. For example, in the situation of “diffuse" pollution (i.e., non-point source pollution), emissions produced by various polluting actors are very difficult to be perfectly observed (O’Shea, 2002). Consequently, several studies indicated that precisely measuring the emissions is very costly or even impossible. Secondly, the effect of monetary policies may not be always sustainable in the long-run (Ashenmiller, 2011; Lefebvre and Stenger, 2020). Several studies have shown that environmental conservation programs cannot be easily achieved if they do not take social factors (e.g., social influence, norms, etc.) as well as individual social-psychological factors (e.g., attitudes towards the pro-environmental behaviors or concern about the negative impacts of the environment, etc.) into account (Pelletier et al., 1999). For instance, people may not continue to put more efforts in protecting the environment (e.g., doing recycling, saving energy, etc.) if they observe that their neighbors or friends are not doing so (Kollmuss and Agyeman, 2002; Thomas and Sharp, 2013).

From the beginning of the 21th century, non-monetary or social incentives including certificate, labeling, social feedback and social influence have been widely assessed by many researchers (Bjørner et al., 2004; Klooster, 2005; Nolan et al., 2008). In one study, the authors have shown that forest certification successfully helps to promote the sustainable forest management and biodiversity maintenance on 124 million ha (3.2%) of world’s forest (Rametsteiner and Simula, 2003). In this regard, social incentives could be seen as appropriate and potential instruments to promote environmental sustainability. However, in their study, the authors also argued that the certification would not provide any improved competitiveness to the industries which have already had a tie/strict control in forest management (Rametsteiner and Simula, 2003). In other words, even good environmental policies that have already successfully implemented in several communities could face a failure in some other areas. Another example should be considered is global climate change, which requires collective actions between countries to tackle global climate issue (Ostrom, 2010). Thus, whether countries will make efforts to reduce greenhouse gas emissions or they will have incentives to free-ride on their neighborhood countries’ constructive behaviors? In other words, an environmental goal may not be easily achieved if we do not motivate people to behave positively and collectively toward the environment.

Therefore, in the first Chapter, we use the meta-analysis of 125 existing studies to shed light into the strength and relevance of seven groups of social incentives (external and internal social influence, network including network size, network connection and leadership and trust including trust in institutions and trust in others) in promoting pro-environmental behaviors.

0.2.1 Chapter 1: Social incentive factors in interventions promoting sustainable behaviors: A meta-analysis

Based on a meta-analysis, this Chapter highlights the strength and relevance of several social incentive factors with respect to pro-environmental behavior, including social influence, network factors (like network size, network connection, and leadership), trust in others, and trust in institutions. In particular, internal social influence is defined as internal motives such as, attitudes, personal norms, intrinsic motivation or self-evaluation/-enhancement resulting from the social competition process. External social influence is defined as external motives such as, extrinsic motivation, expectation of others, or social norms for individuals or society about what they should do. Network factors include network connection (degree of connection between individuals), network size (number of individuals in the network) and leadership (the presence of a leader in the network). Network connection is the degree of connection or the relationship between individuals and others including friends, neighbors, environmentalists and environmental organizations. Network size captures the number of friends, neighbors or co-workers involved in pro-environmental actions or environmental associations that individuals participate in. Leadership is a factor that individuals influenced by their leaders' pro-environmental behaviors. Trust includes trust in institutions (government, public institutions, etc.) and trust in others (friends, neighbors, family, etc.).

The dataset in our study was built using the Web of Science, Google Scholar, PubMed, SagePub, and ScienceDirect databases, and some other relevant journal websites. With systematic keyword searches, we first did the abstract analysis and collected all of the empirical studies, including published and unpublished works (more than 1500 papers). We eliminated all the papers that did not provide enough information to calculate standard errors of effect size (i.e. t-values, p-values, confidence intervals or significance levels). We eventually ended-up with 125 studies in the last step. These 125 studies led to 185 observations in our meta-analysis data (in some papers, the authors used more than one social variables to examine the impacts on pro-environmental behavior).

Firstly, our results suggest that social influence is necessary for the emergence of pro-environmental behaviors. More specifically, social influence that is internal (i.e., that motivates people to change their perceptions and attitudes) is very important to promote pro-environmental behaviors. In addition to internal social influence, our results also suggest that external social influence also results in a positive impact on pro-environmental behaviors but is less effective compared to internal influences. This result is in line with the existing literature that internal social motives are better than external ones because they guide people into changing their behaviors, whereas external influences can drive people to perform a certain action though compliance and identification, but it is not enough to motivate them to change their perceptions and attitudes toward a sustainable behavior. This finding implies that impacts of an environmental policy can be under-estimated if policy-makers do not include social influence in their decisions regarding environmental issues.

Secondly, network connection encourages pro-environmental behavior, meaning that the effectiveness of a conservation policy can be improved if connections among individuals are increased. This result does not support an existing conjecture which hypothesizes that increasing interactions between individuals in a large structure can be bad for social conservation behavior. Finally, trust in institutions can dictate individual behavior in a way that could shape policy design and generate desired policy outcomes. In other words, a successful environmental policy depends largely on trust in institutions through increased transparency, communication strategy, and interaction with populations, etc.

0.3 The role of networks in promoting pro-environmental behavior: Theoretical approaches

Several studies have demonstrated that connections between people would link to the connections between their behaviors (Jackson, 2010; Centola, 2010; Gould et al., 2019). Existing literature also indicated that individuals' decisions can be influenced by others even without being aware of it (Cialdini, 1987; Nisbet et al., 2009). In recent years, numerous theoretical studies have been conducted to study the impact of networks in shaping individuals' behaviors: the relationship between networks and individual contributions to public good have received the most research attention (Bramoullé et al., 2007; Santos et al., 2008; Jackson, 2010); network plays a key role in promoting the pro-social behaviors (Frey and Meier, 2004); social network model of peer effects in criminal decisions (Patacchini and Zenou, 2012). There are some studies that focused on the role of networks in promoting pro-environmental behaviors, e.g., providing environmental messages in different networks could help to encourage the common pool resource conservation (Mantilla, 2015) and how information diffuses into different networks could help to reduce the fish by-catch (Barnes et al., 2016).

While the network model has been widely studied in the literature of public good game, a handful of theoretical evidence has been found in studying the role of networks in promoting individual resource conservation in common pool resource game. Similar to public goods, common pool resources are also non-excludable. But, a main difference between them is the rivalry property: public good can be consumed without reducing availability for others, while consuming common pool resources will decrease the available resources for others (i.e., subtractability property). As a result, while public goods may suffer a free-rider problem because of the lack of contributions, common pool resource would otherwise face a problem of the “tragedy of the commons" because of the over-exploitation (Hardin, 1968). These properties (excludability and subtractability) therefore make the management of common pool resources (CPRs) become especially complex because it is hard to prevent people to subtract units from a CPR (e.g., forest, ocean, fisheries, atmosphere, etc.).

While several existing literature supported the theory of Hardins (i.e., the theory of the tragedy of commons) by indicating that open-access natural resources would undoubtedly lead to the over-exploitation problem (Bromley and Cernea, 1989; Pearce and Turner, 1990), Ostrom argued that one could achieve the successful management of CPRs with property rights and government regulations (Ostrom et al., 1994). For instance, in her book, Ostrom also cataloged several examples in which communities have successfully managed the CPRs without any help of the central government, from 16th century Alpine shepherds managing grazing lands to the year of 1980s Japanese villages managing communal forests (Ostrom, 1990). Following the study of Ostrom, Chaudhuri (2011); Bowles and Gintis (2011) and many others, suggested that human cooperation in managing the common could emerge and persist under stable institutions.

In addition, some studies showed that people are willing to contribute to a public good if they know that others also contribute (i.e., conditional cooperation) Arrow (1970); Frey and Meier (2004). In this sense, ones may be motivated to reduce their extractions of the CPRs if they observe the conservation efforts of others. The others could stand for other people in the community or their close friends (or neighbors) (i.e., the ones who they connect to). Several empirical studies indicated that networks could play an important role in mitigating the over-extraction problem (i.e., “tragedy of the commons"), especially when the populations dependent highly on common properties, have close proximity and enduring social ties (Cárdenas et al., 2015). Other studies showed that informational sharing through a social network could help restrain the resource extraction (Barnes et al., 2016). Social network is therefore a good starting point to explain how individuals could behave pro-environmentally towards common resource extraction.

Therefore, in Chapters 2 and 3, we aim to study in the role of networks in encouraging the resource conservation behaviors in the common pool resource game. In particular, our objective in Chapter 2 is to study how assimilation in social comparison (i.e., individuals compare their behaviors with their direct neighbors) in different types of networks (e.g., circle, star or complete network, etc.) impact individuals' behaviors in extracting a common pool resource. In Chapter 3, we also investigate individual conservation behaviors in the common pool resource game by taking into account the social influence (i.e., individuals benefit from their neighborhood conservation effort) in endogenous network. In this Chapter, the network will not be given by the central planner but it will be formed by individuals themselves (i.e., endogenous network), agents have to pay a cost to initiate a link with other and a link is established if and only if the cost of linking is lower than the benefit of the link (i.e., linking condition is satisfied).

0.3.1 Chapter 2: Social comparison in networks: A common pool resource game

This study investigates how the assimilation in social comparison (i.e., changing behavior in order to fit in with a group) in different network structures (i.e., empty, star, circle and complete network) could impact individual behaviors in extracting a common pool resource. Assimilation is when an individual can identify the similarities between his/herself and the others, while contrast refers to the heightened admiration/self-esteem that one achieves after distancing oneself from others (Kühnen and Hannover, 2000).

In our model, we consider that individuals care about the behaviors of the agents that they connect to (i.e., friends or neighbors). In other words, each agent is located in a given network and he or she compare his or her action to their direct neighbors (i.e., social comparison in network). We assume that the social comparison is assimilative, meaning that one changes his or her behavior in order to minimize the difference/distance between him or her and the others (i.e., the "conformity"). We consider the exogenous network in order to observe the causal effect of network on individual behavior as network structures vary. We use the static framework of the Nash equilibrium to examine the outcome of the CPR game under assumptions: each agent in a network has to decide how much effort to put in extracting the common resource and as the same time takes his or her direct neighborhood behaviors into account in order to maximize his or her personal utility.

Our results suggest that the social comparison could help to shape individual behaviors in the way that it helps to promote the common resource conservation. However, the assimilation effect on individual conservation behavior depends conditionally on different network structures. In particular, a network with fewer connections is better than the one with more connections in order to avoid the over-exploitation problem. Additionally, the assimilation in comparison performs sufficiently well in centralized networks (like a star network) compared to decentralized networks (like a circle or complete network) in incentivizing individuals to conserve the common pool resource.

Regarding the policy implication, it is important for policymakers to carefully take the different types of network structures (i.e., social structure) into account before implementing any policy (or intervention) that promote the resource conservation using the assimilative comparison. A good way to motivate the CPR conservation is to promote the assimilation in the centralized network. On the other hand, we can promote the social comparison in the decentralized network but it is important to keep a relatively low assimilation effect in order to avoid the destruction of CPR. It is therefore also essential to provide information about how important the resource conservation to the key players in the network (e.g., a central player in the star network) in order to more effectively incentivize the resource conservation.

0.3.2 Chapter 3: Common pool resource game on endogenous network

In this Chapter, we investigate how the social influence in endogenous network (i.e., links are formed by individuals themselves) could impact individual behaviors in a common pool resource game. Moreover, how individual resource extractions are linked to network connection (i.e., fraction of friends or neighbors). Additionally, at which level of social influence, cost of linking and network size, the system of a CPR game is locally stable (i.e., sustainable extraction of the CPR).

We consider in our model that individuals will take their neighborhood behaviors (i.e., agent's direct neighborhood behaviors in the network) into account before taking their decisions. In this study, we use the static framework of the Nash equilibrium to examine the outcome of the CPR game under assumption of social influence (agents are influenced by their direct neighborhood behaviors). Since extraction efforts and network connections (i.e., the total number of direct neighbors over the total number of agents or the fraction of friends or neighbors) are costly, agents have to decide how much effort to put in extracting the resource and how many network links to make a connection to in order to maximize their personal utilities. It should be noted that an agent i will initiate a link to j if and only if the linking cost is lower than the benefit gains from initiating the link, such that $\eta g_{ij} \leq \delta g_{ij}(\bar{x} - x_j)(\bar{x} - x_i)$, where η is the linking cost parameter; $g_{ij} = 1$ if there is a link between i and j; δ is the social influence parameter; $\bar{x} = \bar{X}/N$ is the individual's extraction effort capacity with N agents and $\bar{X}$ amount of resource capacity; x_i and x_j are the extraction effort of i and j, respectively. Thus, $\bar{x} - x$ is the agent's conservation effort.

We find that the presence of networks helps to shift agents' behaviors from strategic substitute to strategic complementary. And if the best response is strategic complementary, incentivizing one agent would then lead to a reduction of extraction in his or her network. Additionally, there is a negative relationship between network connection and agents' extraction of a CPR. However, it is necessary to have either a low cost of linking (i.e., a cost for initiating a link with other agent) or a strong social influence to encourage agents to initiate links with others and thus helps to promote the resource conservation. Moreover, depending on the different parameters of the linking cost, social influence and network size, the CPR game exists one unique locally stable equilibrium. Our results also indicate that the system of a CPR game is locally unstable if there are more than six agents competing in extraction of a CPR. This means that when the network size increases, we are more likely to witness a complete destruction of the common resource (Saijo et al., 2017). Therefore, we suggest that policymaker or future research should carefully take network size into account before designing a program which uses social influence in networks to encourage individuals to conserve the common resources.

Since at the beginning, we assume a situation in which agents care about their neighborhood conservation effort, our results support the idea that promoting social influence in networks is good for encouraging resource conservation because agents will be more likely to conserve the common good as long as they could benefit from their neighborhood conservation efforts. However, in order to encourage the network connection, it is necessary to keep a sufficiently low cost of linking and/or high social influence. In our paper, we could observe agents' behaviors changes as social influence parameter varies. For instance, in the presence of strong social influence, agents would have higher incentives to form links with others, and thus it helps to conserve the common resource. However, a strong or weak social influence through network in reality depends on how strong the social norm in the agent's network, but the emergence of social norm is out of scope of this study. Thus, it is worth to be deeply investigated in future study because social norms influence the social influence parameter and thus determines whether it is beneficial or not for an agent to initiate a link with his or her neighbors.

0.4 The role of networks in encouraging organic farming in Vietnam: Experimental approaches

In recent years, we have currently relied on conventional farming which is a widely used method in industrial agriculture to produce the majority of the food we eat. However, this type of farming technique is facing couple of issues that have threatened its future. In conventional farming, only 20 to 30% of the nutrients get absorbed by plants, while remaining portion of chemical residues dissolves in water quickly, creating groundwater pollution (Liu et al., 2016). Ultimately products from chemical farming has lost the food value (Clark et al., 1998). Chemically adulterated foods could seriously affect consumers' health. For example, cancer, the most common deadly disease of today has a direct link with pesticide adulteration of the foods we eat (Rodgers et al., 2018; Horrigan et al., 2002).

From the economic perspective, the production cost of conventional farming has rapidly gone up because farmers are more and more relied on hybrid seeds, fertilizers and pesticides from outside source. Consequently, it makes the profits from conventional farming become less profitable. As a result, this is a major reason that younger generations of farmers in developing countries have to search for opportunities in the cities (Gartaula et al., 2012). Governments in many developing countries like Vietnam have announced loan packages/subsidies instead of attending the real cause for the situation. If the situation continues for long, poor people may have to die due to hunger. Thus, a more sustainable agriculture is needed as a solution for this complicated situation (Huang et al., 2002; Horrigan et al., 2002).

Organic farming is a broad based farm management system. It improves the health of plants and other living creatures, and thus it helps to enrich and protect bio-diversity. The main features of organic farming include optimum use and conservation of locally available natural inputs, increasing soil fertility over a period of time and protecting soil micro-flora, etc. Organic farming aims to produce healthier food to feed and to protect the health of the consumers. Self-dependencies of farm inputs will help to increase the profitability of the farm. If farming becomes more profitable, the migration of population to cities will then come down. As a result, organic farming can therefore give solutions to mitigate the negative impacts on the environment, as well as to reduce social imbalances (Liu et al., 2016; Cui et al., 2018).

In recent years, we observe a relatively high adoption rate of organic farming in some developed countries due to the high awareness of the health problems caused by the consumption of contaminated foods, the negative effects of environmental degradation and especially the appropriate support from governments and international organizations like European Union and International Federation of Organic Agriculture Movements (IFOAM) (Reisch et al., 2013)[1]. In many developing countries, conventional farming helps to provide enough food for the population and generate surplus for exports. However, conventional farming method becomes unsustainable as evidenced by declining crop productivity, environmental degradation, chemical contamination, etc. In other developing countries like Vietnam, the situation is even worse: farmers are using pesticides overtly and without restraint.

[1]IFOAM is first found in France in 1972. There are about 600 member organizations spreading over 120 countries. IFOAM undertakes a wide range of activities related organic farming such as exchange information and knowledge among its members.

In the context of Vietnam, according to the report of the Ministry of Agriculture and Rural Development (MARD) (August 2018), Vietnam imported 79 million USD worth of pesticides and raw materials (about 1,800 billion VND), raising import value of pesticides and raw materials in the first eight months of 2017 to over 660 million USD (over 15,000 billion VND), nearly 47% increase over the same period of 2016. The statistics show that Vietnam is increasingly importing more pesticides and raw materials and the import of pesticides and plant protection chemicals has increased continuously in the last few decades due to the expansion of cultivated area and intensive cultivation of many crops. However, excessive use of chemicals in agriculture has caused severe consequences for the soil and water environment as well as the quality of agricultural products (Savci, 2012).

According to the theory of social and economic network, individuals always link to a network in which they interact and exchange information with others such as a network of friendship or neighborhood (Jackson, 2010). In recent years, thanks to the network of social relationship, information on the social media can spread incredibly fast in not only Vietnam but all over the world. In agriculture, farmers could also not only link to the online networks of farmers, but more importantly to the offline networks, including neighborhood farmers, friends and even the agriculture organizations in which they could share information, ideas, and thoughts about new farming methods. However, organic farming still spreads much more slowly and it is predicted to take decades in order to reach widespread adoption.

Several studies have shown that a potential constraint of the low rate of adoption is lack of credible information about organic farming (Conley and Udry, 2010). Do farmers lack of information about the organic farming method? In many cases, farmers personally know that putting chemicals in the plants is bad, but they are care more about productivity and willing to use more and more pesticides overtime to ensure a high productivity because quality of soil is declining overtime. Government and social media provided information about the negative effects of chemical farming, environmental degradation and contaminated food to not only farmers but consumers. But, it seems not sufficient to promote farmers to move towards organic agriculture. For instance, a farmer said to the social media that "we know that the use of pesticides is harmful to consumers and the environment, but not using harmful pesticides means risk tolerance like the weeds overrun, yellow snail attack, etc.". Therefore, it is important to study how to effectively encourage farmers to move toward a more sustainable agriculture.

In order to response to this question, we investigate how the role of networks could encourage farmers to move toward organic farming using experimental data in Northern Vietnam. In particular, in Chapter 4, we use the data from a contextualized lab-in-the-field experiment to investigate the role of networks, social comparison and information nudge in promoting farmers' investment decisions in organic farming. The role of networks and leadership in encouraging organic farming is studied in Chapter 5 using discrete choice experiment.

0.4.1 Chapter 4: Drivers of organic farming: Lab-in-the-field evidence of the role of social comparison and information nudge in networks in Vietnam

This Chapter considers the responses of farmers' investment decisions in organic farming using different experimental treatments including network structures, social comparison and information nudge. In this study, we investigate why smallholder farmers are reluctant to adopt pro-environmental practices, notably organic farming, in Vietnam. We conducted 22 experimental sessions in August 2019 in four different provinces in the North of Vietnam to provide better understanding on social incentives and the role of networks on farmers' decisions to invest in organic farming. We have totally 220 smallholder farmers took part in a field experiment using IPad.

The experiment was implemented with 11 experimental scenarios, resulting from the combination of the types of network structures, the presence of social comparison and information nudge treatment. The experiment consisted of four parts. In the first part, we ran a lottery-choice task to capture the farmers' sensitivity to risk aversion. The amount of money that was not invested was used as a relative indicator of risk aversion. In the second part, farmers participated in a simple organic investment game with empty network, no social comparison nor information nudge in a repeated 5-period game. In the third part, the network experiments have been run. There are 2 main treatment variables in our experiment: social comparison and the social comparison combined with information nudge. The control treatment is the “no treatment" with either no “social comparison" or “information nudge". We test these two treatments and the control in four different types of network structure (empty network, circle, star and complete networks). Social comparison is an information about the average investment of the total group after each round, given to all the farmers in the network. In the treatment “social comparison combined with information nudge", each subject received additional information about the socially optimal level of investment at the beginning of each round. The third part of the experiment was repeated 10 times. In the fourth part, qualitative and quantitative information (e.g., age, gender, farm size, household size, type of residence, individual and household income, health, etc.) have been collected from the participants using survey questionnaires. We also elicited information on a number of environmental concerns via 15 NEP questionnaires to help us identify the individual perceptions toward the environment (Dunlap et al., 2000).

We find that network plays a key role in encouraging the adoption of organic farming. However, this effect differs following the types of network (circle, star, or complete network) indicating that the role of individuals and the number of individual connections matter. This result is in line with the literature that networks with more connections are better than the networks with fewer connections in facilitating the coordination (McCubbins et al., 2009). This result suggests also that the network-based approach can be considered as a cost-effective method for policymaker to incentivize farmers to behave positively toward organic agriculture (Beaman and Dillon, 2018). Secondly, our analysis also reveals that the treatment “social comparison combined with information nudge" positively impacts the farmers’ decisions regardless of the types of networks. The treatment “social comparison" gives less clear-cut results as there is a positive and significant effect only in the circle network. Finally, some of the control variables (age, gender, health, belonging to a farmer’s association, being concerned with organic farming) are significant to explain the decision to invest in organic farming. For instance, female farmers are less likely to invest in organic farming than males. Older farmers seem to invest more than the younger ones in organic farming. Other variables like NEP, education, risk aversion, income, farm size do not have any significant impact on farmers’ investment decisions.

According to these findings, our study suggests that policymakers can rely on farmers’ network structures and the social comparison as well as information nudge to enhance farmers’ decisions to adopt a more sustainable agriculture in Vietnam. Our results suggest as well that there is a possibility of crowd-in effect, as the effect of both social comparison and information nudge exceeds the effect of social comparison. It is interesting for further study to investigate the underlying mechanism of crowding in and out in social nudges (comparison and information nudges), as they have important implication in securing the sustainable agriculture.

0.4.2 Chapter 5: Farmers’ preferences towards organic farming: Evidence from a choice experiment in Northern Vietnam

In this Chapter, we investigate farmers’ preferences to adopt organic farming using the discrete choice experiment with totally 586 farmers in Northern Vietnam. The discrete choice experiment was conducted to measure how various market factors (including sale contract and organic logo with traceable code) and non-market factors (including training and technical advice, leaders and neighbors in the village doing organic farming) could influence farmers’ decisions in adopting organic farming. The choice experiment presented respondents with multiple choice scenarios. Each time involving a hypothetical situation, farmers were asked to choose one among two unlabeled “organic farming" alternatives (organic option 1 and 2) and a “status quo" alternative. The “status quo" is chosen if farmers decide to choose neither organic option 1 and option 2. The two alternative “organic" options are described by a number of different attributes.

The experiment firstly aims to analyze farmers’ preferences for organic farming, presented by the first attribute “Training and technical advice". This is defined as practical lessons freely delivered to farmers in order to improve their knowledge about organic farming, as well as about organic farming practices. In addition to the “Training", farmers would have technicians or specialists in the local area to advise them to do organic farming. Secondly, the sensitivity to different sale contracts in organic farming, presented by the attribute “Sale contract". This is defined as a sale contract between farmers and buyers. The buyers could be the retailers (supermarkets, companies), cooperatives or direct consumers. We have two types of contracts: a contract with fixed guaranteed prices and with flexible prices in five-year periods. Thirdly, the experiment also includes the attribute “Traceability", which is a traceable code going along with the organic logo on each organic product. This indicates that farmer’s products have already gone through strict quality control and thus consumers can easily distinguish between organic products and non-organic ones. Fourthly, the two last attributes “Neighbor" and “Leadership" indicating the presence of neighborhood farmers and leaders in the village doing organic farming. Finally, the “cost" attribute is a major element using to capture farmers’ willingness to pay for organic farming. The cost includes 6 levels which are in terms of percentage increase in production cost, 0%, 10%, 30%, 60%, 100%, 150%. The additional cost per unit is used to more accurately capture farmers’ willingness to pay because farmers often produce different agricultural products (i.e., product diversification). Another reason that the relative cost is applied, is because farmers who produce same agricultural products but in different rural areas may also have a very different production costs.

Our results suggest that the “Sale contract" with either flexible or guaranteed prices is a major component explaining farmers’ willingness to adopt organic farming. This is because the agricultural product price commitment is seen by farmers as an opportunity for supporting organic agriculture. This result is in line with the literature of “contract farming" (i.e., purchaser provides farmers credit, technical advice, market service, etc. In return, farmers produce certain quantity and quality products and sell them to purchaser), indicating that such arrangement could contribute positively to farmers’ revenue in particular and to growth and poverty reduction in general (Weiss and Khan, 2006; Bolwig et al., 2009).

Furthermore, “training and technical advice" attribute is also a prominent factor that can be used to motivate farmers to move toward organic agriculture. This is because smallholder farmers often have more difficulties (e.g., too costly or lack of information and knowledge) to access organic farming practices compared to large-scale farmers. Thus, it is necessary to have local advisors and intensive trainings/lessons to motivate them to move toward organic farming. This result is also in line with existing studies which suggested that technical knowledge of organic farming practices is one important barrier to organic transition (Brock and Barham, 2013; Dimitri and Baron, 2019).

Finally, "neighbor" attribute, measuring whether there is a presence of neighbors in farmer's village are doing organic farming, is also important to encourage farmers to change their farming method to organic. This suggests that farmers seem to be influenced by their neighbors in adopting organic farming. This is because neighborhood farmers are sometimes a valuable source of information and knowledge for farmers, especially when farmers in the rural area often have good relationships with their neighbors. Therefore, the role of networks (i.e., neighborhood connection) is also important and need to be taken into account by policymakers or future research.

0.5 Conclusion

In conclusion, this dissertation contributes to existing literature by deeply investigating the impacts of social incentives (including social comparison and information nudges) in different networks (including exogenous and endogenous networks) in both theoretical and empirical ways. The results of this dissertation suggest that promoting network connection and social incentives (e.g., internal social influence that motivates people to change their perceptions and attitudes) could help to encourage the pro-environmental behavior (see Chapter 1). This result is confirmed by the results of our discrete choice experiment (see Chapter 5) since farmers who choosing organic farming alternative, are willing to pay to have farmers in their neighborhood doing organic farming. This is because neighborhood farmers are valuable sources of information, knowledge and motivation that could help farmers to move towards organic farming. Our results of the CPR game in endogenous network (see Chapter 3) also suggest that it is important to promote a sufficiently low cost of linking (i.e., a cost that one has to pay in order to initiate a link with other) to incentivize individuals to connect to others (i.e., promote network connection) and thus helps to encourage the common pool resource conservation. Consequently, promoting socialization or network connection is essential to motivate individual to behave positively towards the environment.

Moreover, providing social incentives (e.g., social comparison and information nudges) in networks could help to promote pro-environmental behavior. However, network structure is important and needs to be carefully taken into account since our results in Chapter 2 indicate that social comparison could have different impacts on individual behaviors depending on the types of networks (e.g., circle, star or complete network). More specifically, in the presence of assimilation in social comparison (e.g., individuals compare their behaviors to their direct neighbors' behaviors), it is more effective to motivate agents in centralized networks (like a star network) to conserve the common pool resource compared to decentralized networks (like a circle or complete network). Our results of the *lab-in-the-field* experiment (see Chapter 4) also suggest that social comparison treatment (i.e., individuals received information about the average group investment in organic farming) perform sufficiently well in a circle network (i.e., decentralized network with fewer connections) in encouraging farmers to move towards organic farming than in a star and complete network (i.e., decentralized network with more connections). Therefore, it is essential to carefully take the network structures into account before promoting the social incentives (e.g., social comparison and information nudges) to effectively motivate individuals to behave positively toward the environment.

However, in reality, it is very difficult for either policymaker or individuals themselves to fully observe the actual network structure as well as each individual behavior or action in the network. This means that providing social incentive like social comparison (e.g., information about the average group behavior) could be an effective way to promote the pro-environmental behavior. Additionally, it is always easier to observe the behaviors/actions of one or two most important agents in the network than fully observe all agents' behaviors. Thus, another alternative is to motivate the role of the central agent (i.e., a leaders or influential person, etc.) to promote the pro-environmental behavior since we observe that motivating the role of central agents in the star network could help to significantly promote the common resource conservation (see Chapter 2).

Bibliography

Allcott, H. and T. Rogers (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review 104*(10), 3003–3037.

Arrow, K. (1970). Political and economic evaluation of social effects and externalities. In *The Analysis of Public Output*, Chapter 1, pp. 1–30. National Bureau of Economic Research.

Ashenmiller, B. (2011). The effect of bottle laws on income: New empirical results. *American Economic Review 101*(3), 60–64.

Barnes, M. L., J. Lynham, K. Kalberg, and P. Leung (2016). Social networks and environmental outcomes. *Proceedings of the National Academy of Sciences 113*(23), 6466–6471.

Baumol, W. J. (1972). On taxation and the control of externalities. *The American Economic Review 62*(3), 307–322.

Beaman, L. and A. Dillon (2018). Diffusion of agricultural information within social networks: Evidence on gender inequalities from Mali. *Journal of Development Economics 133*, 147–161.

Bjørner, T. B., L. G. Hansen, and C. S. Russell (2004). Environmental labeling and consumers' choice—an empirical analysis of the effect of the Nordic Swan. *Journal of Environmental Economics and Management 47*(3), 411–434.

Bolton, G. E. and A. Ockenfels (2000). ERC: A theory of equity, reciprocity, and competition. *American Economic Review 90*(1), 166–193.

Bolwig, S., P. Gibbon, and S. Jones (2009). The economics of smallholder organic contract farming in tropical Africa. *World Development 37*(6), 1094–1104.

Bowles, S. and H. Gintis (2011). *A Cooperative Species: Human Reciprocity and Its Evolution*. Princeton University Press.

Bramoullé, Y., R. Kranton, et al. (2007). Public goods in networks. *Journal of Economic Theory 135*(1), 478–494.

Brock, C. C. and B. L. Barham (2013). 'Milk is mil': Organic dairy adoption decisions and bounded rationality. *Sustainability 5*(12), 5416–5441.

Bromley, D. W. and M. M. Cernea (1989). *The Management of Common Property Natural Resources: Some Conceptual and Operational Fallacies*. World Bank Publications.

Brülisauer, M., L. Goette, Z. Jiang, J. Schmitz, and R. Schubert (2020). Appliance-specific feedback and social comparisons: Evidence from a field experiment on energy conservation. *Energy Policy 145*, 111742.

Cárdenas, J. C., C. Mantilla, and R. Sethi (2015). Stable sampling equilibrium in common pool resource games. *Games 6*(3), 299–317.

Centola, D. (2010). The spread of behavior in an online social network experiment. *Science 329*(5996), 1194–1197.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: A selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Cho, S. and H. Kang (2017). Putting behavior into context: Exploring the contours of social capital influences on environmental behavior. *Environment & Behavior 49*(3), 283–313.

Cho, Y. N., A. Thyroff, M. I. Rapert, S. Y. Park, and H. J. Lee (2013). To be or not to be green: Exploring individualism and collectivism as antecedents of environmental behavior. *Journal of Business Research 66*(8), 1052–1059.

Cialdini, R. B. (1987). *Influence*, Volume 3. A. Michel Port Harcourt.

Clark, C. F., M. J. Kotchen, and M. R. Moore (2003). Internal and external influences on pro-environmental behavior: Participation in a green electricity program. *Journal of Environmental Psychology 23*(3), 237–246.

Clark, M. S., W. R. Horwath, C. Shennan, and K. M. Scow (1998). Changes in soil chemical properties resulting from organic and low-input farming practices. *Agronomy Journal 90*, 662–671.

Conley, T. G. and C. R. Udry (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review 100*(1), 35–69.

Cui, Z., H. Zhang, X. Chen, C. Zhang, W. Ma, C. Huang, W. Zhang, G. Mi, Y. Miao, X. Li, et al. (2018). Pursuing sustainable productivity with millions of smallholder farmers. *Nature 555*, 363–366.

Diederich, J. and T. Goeschl (2014). Willingness to pay for voluntary climate action and its determinants: Field-experimental evidence. *Environmental and Resource Economics 57*(3), 405–429.

Dimitri, C. and H. Baron (2019). Private sector support of the farmer transition to certified organic production systems. *Organic Agriculture*, 1–16.

Dufwenberg, M., P. Heidhues, G. Kirchsteiger, F. Riedel, and J. Sobel (2011). Other-regarding preferences in general equilibrium. *The Review of Economic Studies 78*(2), 613–639.

Dunlap, R. E., K. D. Van Liere, A. G. Mertig, and R. E. Jones (2000). New trends in measuring environmental attitudes: Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues 56*(3), 425–442.

Espinosa-Goded, M., J. Barreiro-Hurlé, and E. Ruto (2010). What do farmers want from agri-environmental scheme design? A choice experiment approach. *Journal of Agricultural Economics 61*(2), 259–273.

Frey, B. S. and S. Meier (2004). Social comparisons and pro-social behavior: Testing "conditional cooperation" in a field experiment. *American Economic Review 94*(5), 1717–1722.

Gartaula, H., A. Niehof, and L. Visser (2012). Shifting perceptions of food security and land in the context of labour out-migration in rural Nepal. *Food Security 4*(2), 181–194.

Gould, R. K., N. M. Ardoin, J. M. Thomsen, and N. Wyman Roth (2019). Exploring connections between environmental learning and behavior through four everyday-life case studies. *Environmental Education Research 25*(3), 314–340.

Gouu, R. V. (1993). Collective action and network structure. *American Sociological Review 58*(2), 182–196.

Grund, T., C. Waloszek, and D. Helbing (2013). How natural selection can create both self- and other-regarding preferences, and networked minds. *Scientific Reports 3*, 1480–1480.

Hardin, G. (1968). The tragedy of the commons. *Science 162*(3859), 1243–1248.

Horrigan, L., R. S. Lawrence, and P. Walker (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives 110*(5), 445–56.

Huang, J., C. Pray, and S. Rozelle (2002). Enhancing the crops to feed the poor. *Nature 418*, 678–684.

Jackson, M. O. (2010). *Social and Economic Networks*. Princeton university press.

Jackson, M. O., B. W. Rogers, and Y. Zenou (2017). The economic consequences of social-network structure. *Journal of Economic Literature 55*(1), 49–95.

Klooster, D. (2005). Environmental certification of forests: The evolution of environmental governance in a commodity network. *Journal of Rural Studies 21*(4), 403–417.

Kollmuss, A. and J. Agyeman (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research 8*(3), 239–260.

Krawczyk, M., A. Bartczak, N. Hanley, and A. Stenger (2016). Buying spatially-coordinated ecosystem services: An experiment on the role of auction format and communication. *Ecological Economics 124*, 36–48.

Kühnen, U. and B. Hannover (2000). Assimilation and contrast in social comparisons as a consequence of self-construal activation. *European Journal of Social Psychology 30*(6), 799–811.

Lazaric, N., F. Le Guel, J. Belin, V. Oltra, S. Lavaud, and A. Douai (2019). Determinants of sustainable consumption in france: the importance of social influence and environmental values. *Journal of Evolutionary Economics*, 1–30.

Lefebvre, M. and A. Stenger (2020). Short-& long-term effects of monetary and non-monetary incentives to cooperate in public good games: An experiment. *Plos One 15*(1), e0227360.

Liu, H., J. Meng, W. Bo, D. Cheng, Y. Li, L. Guo, C. Li, Y. Zheng, M. Liu, T. Ning, et al. (2016). Biodiversity management of organic farming enhances agricultural sustainability. *Scientific reports 6*(1), 1–8.

Mantilla, C. (2015). Communication networks in common-pool resource games: Field experimental evidence. *Journal of Economic Behavior & Organization 118*, 215–226.

Marsden, P. V. and N. Lin (1982). *Social Structure and Network Analysis*. Sage Beverly Hills.

McCubbins, M. D., R. Paturi, and N. Weller (2009). Connected coordination: Network structure and group coordination. *American Politics Research 37*(5), 899–920.

McPherson, M., L. Smith-Lovin, and J. M. Cook (2001). Birds of a feather: Homophily in social networks. *Annual Review of Sociology 27*(1), 415–444.

Mekonnen, A., R. Bluffstone, et al. (2017). Does community forest collective action promote private tree planting? Evidence from Ethiopia. *International Business Research 10*(5), 86–106.

Nisbet, E. K., J. M. Zelenski, and S. A. Murphy (2009). The nature relatedness scale: Linking individuals' connection with nature to environmental concern and behavior. *Environment and Behavior 41*(5), 715–740.

Nolan, J. M., P. W. Schultz, R. B. Cialdini, N. J. Goldstein, and V. Griskevicius (2008). Normative social influence is underdetected. *Personality and Social Psychology Bulletin 34*(7), 913–923.

O'Shea, L. (2002). An economic approach to reducing water pollution: Point and diffuse sources. *Science of the Total Environment 282*, 49–63.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Political Economy of Institutions and Decisions. Cambridge University Press.

Ostrom, E. (2010). Polycentric systems for coping with collective action and global environmental change. *Global Environmental Change 20*(4), 550–557.

Ostrom, E., R. Gardner, and J. Walker (1994). *Rules, Games, and Common-Pool Resources*. University of Michigan Press.

Patacchini, E. and Y. Zenou (2012). Juvenile delinquency and conformism. *The Journal of Law, Economics, & Organization 28*(1), 1–31.

Pearce, D. W. and R. K. Turner (1990). *Economics of Natural Resources and the Environment*. Johns Hopkins University Press.

Pelletier, L. G., S. Dion, K. Tuson, and I. Green-Demers (1999). Why do people fail to adopt environmental protective behaviors? Toward a taxonomy of environmental amotivation. *Journal of Applied Social Psychology 29*(12), 2481–2504.

Polman, N. and L. Slangen (2008). Institutional design of agri-environmental contracts in the European Union: The role of trust and social capital. *NJAS - Wageningen Journal of Life Sciences 55*(4), 413–430.

Rametsteiner, E. and M. Simula (2003). Forest certification-an instrument to promote sustainable forest management? *Journal of Environmental Management 67*(1), 87–98.

Reisch, L., U. Eberle, and S. Lorek (2013). Sustainable food consumption: An overview of contemporary issues and policies. *Sustainability: Science, Practice and Policy 9*(2), 7–25.

Robert, N. and A. Stenger (2013). Can payments solve the problem of undersupply of ecosystem services? *Forest Policy and Economics 35*, 83–91.

Rodgers, K. M., J. O. Udesky, R. A. Rudel, and J. G. Brody (2018). Environmental chemicals and breast cancer: An updated review of epidemiological literature informed by biological mechanisms. *Environmental Research 160*, 152–182.

Saijo, T., J. Feng, and Y. Kobayashi (2017). Common-pool resources are intrinsically unstable. *International Journal of the Commons 11*(2), 597–620.

Santos, F. C., M. D. Santos, and J. M. Pacheco (2008). Social diversity promotes the emergence of cooperation in public goods games. *Nature 454*(7201), 213–216.

Savci, S. (2012). An agricultural pollutant: Chemical fertilizer. *International Journal of Environmental Science and Development 3*(1), 73.

Schmalensee, R. and R. N. Stavins (2017). The design of environmental markets: What have we learned from experience with cap and trade? *Oxford Review of Economic Policy 33*(4), 572–588.

Schubert, C. (2017). Green nudges: Do they work? Are they ethical? *Ecological Economics 132*, 329–342.

Schwartz, D., G. Loewenstein, and L. Agüero-Gaete (2020). Encouraging pro-environmental behaviour through green identity labelling. *Nature Sustainability*, 1–7.

Scott, J. (1988). Social network analysis. *Sociology 22*(1), 109–127.

Steg, L. and C. Vlek (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology 29*(3), 309–317.

Thomas, C. and V. Sharp (2013). Understanding the normalisation of recycling behaviour and its implications for other pro-environmental behaviours: A review of social norms and recycling. *Resources, Conservation and Recycling 79*, 11–20.

Van Laerhoven, F. (2010). Governing community forests and the challenge of solving two-level collective action dilemmas-a large-N perspective. *Global Environmental Change 20*(3), 539–546.

Weiss, J. and H. Khan (2006). *Poverty Strategies in Asia: A Growth Plus Approach*. Edward Elgar Publishing.

Chapter 1

Social incentive factors in interventions promoting sustainable behaviors: A meta-analysis[1]

1.1 Introduction

It has been highlighted in the literature that individuals could be incentivized to mitigate environmental issues (e.g., climate change, biodiversity conservation, etc.) via using monetary incentives. As an example, monetary incentives have been successfully implemented to motivate people to protect their living environment, e.g., providing payments based on the quantity of recycled waste or the amount of electricity reduced (Tucker et al., 1998; Thøgersen and Olander, 2003; Elinder et al., 2017). However, the effectiveness of monetary policies is questionable. Firstly, they are costly to implement (Asensio and Delmas, 2015). For example, the Pigovian tax or cap-and-trade emission requires relatively high administrative and monitoring costs in order to be successfully implemented. Secondly, the effect of monetary policies is not always sustainable in the long-run (Ashenmiller, 2011; Lefebvre and Stenger, 2020). Several studies have shown that environmental conservation programs cannot be easily achieved if they fail to motivate people in terms of environmental sustainability: Will people continue to conserve energy if they know that they will not receive any more payments for their efforts in the future (Desbureaux, 2016; Allcott and Rogers, 2014; Zaval, 2016)? Thus, the crowding-out effect of an environmental policy is also important and needs to be taken into account (Cardenas et al., 2000; Werfel, 2017). Thirdly, people's motives can be good drivers of pro-environmental behavior as well (Thøgersen, 2013). While policy-makers mainly focus on how to effectively use monetary incentives to encourage individuals or industries to protect the environment, social

[1]This chapter is based on Nguyen-Van P., Stenger A. and Tiet T. (2020), Social incentive factors in interventions promoting sustainable behaviors: A meta-analysis. *Submitted*.

incentives, which are non-monetary incentives, are also useful tools to mitigate individuals' negative impacts on the environment (Thøgersen, 2013; Bolderdijk et al., 2013).

Several studies have indicated that people may engage in pro-environmental (prosocial) behaviors because of individual social incentives such as social norms or intrinsic/extrinsic motivation, namely "social influence" (Abrahamse and Steg, 2013; Dietz, 2015). Social influence refers to the way in which individuals alter their attitudes and behaviors in response to the demands of their social environment (i.e., expectation of others, conformity or altruism) (Cialdini, Cialdini; Turner, 1991; Cialdini and Goldstein, 2004). For example, providing energy consumption feedback or environmental messages to households could help to encourage energy conservation (Allcott and Rogers, 2014). In this case, if an individual consumes less electricity while others do not, he or she would gain not only a benefit from saving energy but an image reward by comparison with his or her neighbors as well (e.g., the best in the neighborhood) (Griskevicius et al., 2010; Van Horen et al., 2018). Some of existing literature also qualifies social influence as internal and external influences: internal social influence includes altruism, intrinsic motivation or other-regarding preferences; external social influence is linked to norms, extrinsic motivation or a reputation system (Harpine, 2015; Simpson and Willer, 2015). According to the theory of planned behavior (TPB), social pressure or social norms are external influence factors that affect individual intention to perform a target behavior, while attitude and personal norms are internal motives that could explain pro-environmental behavior through intrinsic motivation (Ajzen et al., 1991; Bénabou and Tirole, 2006; Schultz et al., 2007). Additionally, social competition (i.e., social comparative feedback) could internally motivate individuals by generating self-evaluation (i.e., individuals evaluate themselves) and self-enhancement that could encourage people to act and sustain their behaviors overtime because of social competition (Festinger, 1954; Frey and Meier, 2004; Van Der Linden, 2015).[2] Therefore, internal social influence is defined as internal motives such as, attitudes, personal norms, intrinsic motivation or self-evaluation/-enhancement resulting from the social competition process. External social influence is defined as external motives such as, extrinsic motivation, expectation of others, or social norms for individuals or society about what they should do.

However, focusing on individual social incentives when addressing environmental issues may raise several problems: as for monetary contribution, for example, an individual who takes an action to alleviate his or her sense of obligation to help improve environmental quality may then not take any further actions when (s)he realizes that others do not cooperate. This could be defined as a single action bias. Furthermore, for most environmental issues (e.g., biodiversity, deforestation, energy, etc.), it is necessary to have

[2]Competitive behaviors could drive self-evaluation and the necessity of such an evaluation is based on comparison with other people Festinger (1954).

many individuals but most often within the same area who adhere to a conservation program in order to reach a necessary threshold (proportion of individuals in the network) above which a positive program effect can arise. Thus, in addition to social influence, several studies suggest that network factors and individual trust can also be used to promote "collective pro-environmental behaviors", which are behaviors taken together by a group of individuals and including society as a whole (i.e., collective actions) to achieve an environmental target (Gouu, 1993; Van Laerhoven, 2010).

In today's world of social relationships, everyone is linked to a social network (e.g., the limited network of family, friends, relatives, neighbors, co-workers and even acquaintances). Since individuals are linked to each other, other individual behaviors could be an important factor that can be used to motivate a person to perform a specific action (Thaler and Sunstein, 2008). For example, people are more likely to adopt behaviors that are approved by others in order to cultivate or maintain close social relationships with others (Cialdini and Goldstein, 2004). Some studies have shown that people who have been motivated by strong social influences may require pressure from their network to live up to their intentions (De Graaf et al., 2004). Different network structures (characterized by different network size, network connection or degree of connection, and leadership) may have different impacts on individual contributions to a collective good (Gouu, 1993).[3] Besides the network factors, individual trust is an important concept since trust is applicable to the relationship between people (Lewis and Weigert, 1985; Cochard et al., 2004). Higher levels of trust (social and/or institutional) help to ensure stronger social connections which could indeed strengthen individual pro-environmental actions. Without trust among individuals and/or trust in the institutions (government, organizations or leaders), pro-environmental actions may not be sustainable. Therefore, policymakers should pay attention to individual as well as collective actions to achieve an environmental target (Ng et al., 2013).

Taken together, we identified seven different groups of social incentives that can enhance pro-environmental behavior: social influence (including internal and external influence); network factors (including network size, network connection and leadership); and trust (including trust in others and in institutions). Network factors include network connection (degree of connection between individuals), network size (number of individuals in the network) and leadership (the presence of a leader in the network). Network connection is the degree of connection or the relationship between individuals and others including friends, neighbors, environmentalists and environmental organizations. Network size captures the number of friends, neighbors or co-workers involved in pro-environmental

[3]The authors showed that a volunteer who is centrally located in a sparse network (i.e., network with a low degree of connection) has greater impact on others' contributions than the one who is centrally located in a dense and less centralized network Gouu (1993).

actions or environmental associations that individuals participate in. Leadership is a factor that individuals influenced by their leaders' pro-environmental behaviors. Trust includes trust in institutions (government, public institutions, etc.) and trust in others (friends, neighbors, family, etc.). The diagram of these seven groups of social incentives is presented in Figure 1.1. Detail definitions of these social incentive factors are provided in Table 1.2.

Several studies have provided descriptive reviews of this area of research, focusing on how information strategies influence energy conservation (Delmas et al., 2013; Karlin et al., 2015), how social influence approaches can be used to encourage resource conservation (Abrahamse and Steg, 2013; Farrow et al., 2017), presenting comparative studies of household energy conservation (Abrahamse et al., 2005), analyzing determinants and outcomes of belief in climate change (Hornsey et al., 2016), testing behavioral inventions on climate change mitigation (Nisa et al., 2019), and examining the evidence of spillover in pro-environmental behavior (Maki et al., 2019). Although numerous studies have been conducted to assess the effects of social incentives on pro-environmental behavior, the latter are, however, often studied separately (see Table 1.9). In addition, the effectiveness of social incentives that promote pro-environmental behavior has not yet been sufficiently investigated in the literature. We contribute to the literature by addressing all of the seven groups of social incentives together in order to answer the following question: Which social incentives are more effective in encouraging pro-environmental behavior? In response to this question, we conducted a meta-analysis to provide an empirical insight into these seven groups of social incentives.[4] We quantify their strength and relevance with respect to pro-environmental behavior and give some recommendations in terms of public policy. Finally, we take the impact of the aggregation level into account by organizing the seven social incentive groups into three higher aggregated social groups (i.e., social influences, network and trust) and investigate their relative relevance with respect to the metadata.

To the best of our knowledge, we also contribute to the literature by addressing all these 7 groups of the social incentives simultaneously in studying pro-environmental behavior: which social incentives are more effective in encouraging pro-environmental behavior? In response to this question, we conducted a meta-analysis[5] to provide an empirical insight into these 7 groups of social incentives in order to quantify their strength and relevance with respect to pro-environmental behavior and to give some recommendations

[4]Meta-analysis is a well-known statistical and scientific technique that helps to combine the results of multiple scientific studies, to establish evidence-based practice, and to resolve uncertain research outcomes (Gurevitch et al., 2018).

[5]Meta-analysis is a well-known statistical and scientific technique that helps to combine the results of multiple scientific studies, to establish evidence-based practice, and to resolve uncertain research outcomes (Gurevitch et al., 2018).

in terms of public policy. In addition, we also take into account the impact of aggregation level of social incentive factors by gathering the 7 social incentive groups into three higher aggregated social groups (i.e. social influences, network, and trust) and compare the difference between the effectiveness of these 3 and 7 groups of social incentives.

The rest of the paper proceeds as follows. In Section 2, we describe the meta-analysis results. Section 3 is devoted to discussions and a conclusion. Section 4 describes data collection, descriptive statistics and the methodology used. In this section, the problems of heterogeneity and publication bias are also checked to warrant the robustness of the analysis. Since heterogeneity probably exists between studies, the meta-regression model is adapted to take this heterogeneity into account.

1.2 Results

Based on the existing literature, as mentioned above, we divided our discussions about the emergence of pro-environmental action into seven groups of social incentives: internal and external social influence, network factors (network size, network connection, and leadership) and trust (trust in others and trust in institutions) (Bekkers and Schuyt, 2008; Simpson and Willer, 2015). This leads to seven social incentive dummies used in the meta-regressions (network size being the base category). The forest plots in Figure 1.5 - Figure 1.8 show that internal and external social influence, trust in institutions and network connection are key significant factors that could be used to encourage pro-environmental behavior. Our summarized results (Table 1.5, column 4, where the mixed-effect model is applied using partial correlation coefficients) suggest that the effect of internal and external social influence, network connection and trust in institutions on pro-environmental behavior are positive and statistically significant. On the contrary, leadership and trust in others do not have a significant effect on pro-environmental behavior. The standardized coefficients (column 5) suggest that internal social influence is the most effective social incentive (since its value is the highest) followed by external social influence, network connection and trust in institutions.

1.2.1 Social influence

Social influence includes both internal and external social influences. According to external social influence, an individual essentially acts or behaves according to external motives such as expectation of others, extrinsic motivation or social norms. In the case of internal social influence, individuals act under internal motives such as attitudes, personal norms, intrinsic motivation or self-evaluation/-enhancement resulting from social competition.

External social influence. Our meta regression results in Table 1.5 show that there is a positive and significant impact of external social influence on pro-environmental behavior at a 10% significance level. The forest plot in Figure 1.6 suggests that the overall effect of external social influence is positive, even if there are some studies have reported negative results. This means that the presence of external social influence is overall in favor of encouraging pro-environmental behavior but, in some cases, it can discourage environmental conservation. For example, if forest owners' behaviors could not be observed by a community and if there was no regulator to monitor them, then forest owners would collectively choose deforestation, even with strong social expectations (social norms) that forest conservation is important for society (Ledyard, 1995; Desbureaux, 2016). In another example, when asking people how much they are willing to contribute to environmental conservation, individuals will report lower conservation efforts if they know that their profiles and results are invisible to others. People may act collectively and regardless of the demand of the social situation if they know that their actions cannot be observed by others (Lee et al., 2016; Brick et al., 2017). Thus, future studies should take the observability of individual behavior, social identity and many other aspects into account when studying external social influences.[6]

Internal social influence. Regarding the forest plot in Figure 1.5, most of the studies in the literature suggest a positive effect of internal social influence on pro-environmental behavior. Several studies suggested that individuals gain insights about environmental issues and get recognition from their peers through "social comparative feedback".[7] that of their neighboring households As a result, they change and develop more environmentally-oriented behavior because of the self-evaluation/-enhancement process (Festinger, 1954; Robelia et al., 2011). However, one study revealed that comparison feedback may perform badly in encouraging environmental conservation (e.g., soil conservation) because terracing is a demanding soil conservation practice and farmers have low perception of environmental issues (Willy and Holm-Müller, 2013). Thus, if there is a relatively low individual perception of an environmental issue, internal social influence may also fail to promote pro-environmental behavior. In addition to the forest plot, our meta-regression results in Table 1.5 suggest that internal social influence has a positive and significant effect on pro-environmental behavior. The standardized coefficients reported in Table 1.5 indicate that the internal social influences that motivate people to change their perceptions and attitudes are very important to promote pro-environmental behavior. We can

[6]A study in the US showed that Asians, Blacks, and Latinos are more concerned about the environment than Whites, but that they are perceived it as being less concerned than Whites. The difference in social identity and status contributes to the disparity between environmental concern and commitment (Dietz and Whitley, 2018).

[7]Social comparative feedback could be the household consumption report (energy, water, recycling or green consumption) containing the household's consumption and

therefore conclude that the impacts of an environmental policy could be under-estimated if internal social influence is not taken into account.

1.2.2 Network factors

People who have been motivated by strong social influences may require pressure from their network to live up to their intentions (De Graaf et al., 2004). Network including network size, network connection and leadership are factors that can contribute to the emergence of pro-environmental behavior (Gouu, 1993; Ouvrard and Stenger, 2017).

Network connection (which can be defined as the degree of connection between individuals and others in their networks). In a social network, each individual is represented by a social unit (or node). Social units are linked together through social relationships such as friendship or acquaintanceship (Wasserman and Faust, 1994). A strong network connection comes from the strong ties or interactions among individuals inside the network. This is equivalent to what is referred to as the "*good sense of community*".[8] Several empirical studies have shown that the "good sense of community" can directly shape individuals' behaviors and force them to care more about environmental issues (Nepal et al., 2007a; Tesfaye et al., 2012a; Videras et al., 2012). Our results suggest that the effect of network connection is relatively strong, with the standardized coefficient equals to 0.3508 (see the results in Table 1.5). In one study, the authors showed that network has an indirect impact on ecological health because it helps to share information and knowledge across individuals and to promote cooperation among members of the network (Barnes et al., 2016). Thus, a stronger network connection, which is the main characteristic of network structure, is one of the effective social incentives to enhance environmental behavioral change.

Network size (which is the number of individuals in the network who engage in pro-environmental behavior or the number of environmental organizations that an individual participates in). Several studies have indicated that a larger network size is responsible for weaker network connection or less social interaction because individuals in a society or group only make contact or interact frequently with others living close to them (Derksen and Gartrell, 1993; Yau, 2010; Yang et al., 2013). Our forest plot (Figure 1.7) suggests that network size has no effect on pro-environmental behavior. Meta-regression results also support this finding by indicating that other groups of social incentives have positive effects on pro-environmental behavior compared to network size (as the base category).[9]

[8] Good sense of community means that individuals frequently interact with each other and that they care more about their community.

[9] It should be noted that the effect of network size corresponds to the regression intercept. The latter also corresponds to the overall effect size in the meta-regression. Moreover, it represents the effect of the base category for other groups of dummies (more precisely, census data among types of data collection methods and Europe among geographical regions). Consequently, we cannot separately identify the overall effect

(see Table S4, columns (1′) and (3′) with effect size coefficient and partial correlation coefficient as dependent variables, respectively) the intercept may become (significantly or not) negative. This is because the latter also includes the effect of the base category of social incentive (i.e., network size). Hence, increasing network size will not result in a better environmental outcome, ceteris paribus. By comparing this result with the network connection, we would expect that if an increase in the network size is accompanied by a stronger degree of connection between individuals, than the adverse effect of network size can be more than offset by the positive effect of connections between individuals, leading to a pro-environmental action. In other words, when requiring this combination of network size and network connection, the point of vigilance must be to observe the necessary condition of an increase in the connection.

Leadership (which can be defined as the sense of leadership in a network). In order to have a sustainable network, the presence of a good leader appears to be necessary. This leader is responsible for providing information and keeping people connected. For example, some studies showed that a "block leadership" approach treatment[10] has a positive impact on the recycling rate of households because a leader plays an important role in sustaining a connection and providing needed information to households within the leader's network (Burn, 1991; Hopper and Nielsen, 1991). However, the coefficients of leadership in our meta-analysis regression are positive but statistically insignificant compared to the network size (see Table 1.5). This is not surprising because among the positively significant results of leadership, there are some studies that reported the positively small and even negative impact of leadership on pro-environmental behavior (see the forest plot in Figure 1.7).[11] For example, one study indicated that the presence of a leader in groups that have the autonomy to craft governance rules for their environmental resource, can encourage the group's collective action toward resource conservation, but discourage resource conservation when groups are subject to rules imposed by others (Van Laerhoven, 2010).[12]

size, the effect of network size, and the effect of the base category for other dummy groups. A simple meta-regression without variables of interest (i.e., social incentives) and without any control variable gives a very rough estimation of the overall effect size (see Table 3, also corresponding to a test for publication bias). When this meta-regression is increased by social incentive dummies

[10]Block leaders are volunteers who help inform people in their groups about a certain issue.

[11]We also re-estimated the model by excluding one paper that reported a negative impact of leadership, and obtained the same results. Thus, we can be confident that an outlier is not present in our data.

[12]A detailed analysis of the autonomy to craft governance rules would be interesting but is beyond the scope of this paper. Thus, it would be interesting for future studies to take it into account when studying the impact of leadership on pro-environmental behavior.

1.2.3 Trust

Another important social incentive is trust since it is applicable to the relationships among people (Lewis and Weigert, 1985). Higher levels of trust (in institutions or in others) can help to ensure stronger social interactions, which could indeed strengthen the collective action. Pro-environmental action cannot be sustained if there is neither trust among individuals (trust in others) nor trust toward the institutions (government or leaders).

Trust in institutions (which can be defined as individuals' trust in their government, institutions, or their leader). Our meta-analysis results (Table 1.5) show that trust in institutions is a driver of pro-environmental behavior. A lack of trust in government can lead to a negative individual perception of an institutional design/government program and prevent the individual from participating in it. For example, a well-designed agri-environmental contract cannot completely replace a farmer's trust in the government (Polman and Slangen, 2008). The rate of participation in an environmental program can be increased by motivating people and by maintaining and developing institutional trustworthiness (Sønderskov, 2009; Xiao and McCright, 2015).

Trust in others (which can be defined as social trust or individuals' trust in others in the community, like friends, family, relatives and acquaintances). Regarding the forest plot in Figure 1.8, trust in others has a positive overall effect on pro-environmental behavior. Similar to trust in institutions, maintaining trustworthiness between individuals has a positive impact on behavioral changes as shown by numerous studies (Yan et al., 2018). However, our meta-regression results cannot confirm the significant impact of trust in others on pro-environmental behavior (see Table 1.5). Some of the existing literature suggests that trust in others may fail to motivate new attitudes about environmental issues and pollution (Hao et al., 2019). In their study, the authors argued that a higher level of trust within a close network can cultivate a sense of comfort and security and thus makes people less likely to respond to less immediate and indirectly observable environmental issues. One study indicated that trust in others performing resource conservation behavior may have a low impact on resource extraction because of the subtractability property of the common resource (i.e., consuming an additional common resource would decrease the available resources for others) (Beitl, 2014a). As a result, because of the resource constraint, individuals who trust in others performing resource conservation feel that they have no choice but to harvest whatever the environment provides.

1.3 Discussions and conclusion

Our results suggest that to promote pro-environmental behavior in society, policy-makers should focus on at least three issues. Firstly, we find that internal social influence is the most important social incentive that positively affects pro-environmental behavior. This means that internal social influence that motivates people to change their perceptions and attitudes are very important and necessary to promote pro-environmental behavior. In addition to internal social influence, our results also suggest that external social influence also results in a positive impact on pro-environmental behavior but it is less effective compared to internal influences. This result is in line with the existing literature that holds that internal social motives are better than external ones because they guide people into changing their behaviors, whereas external influences can drive people to perform a certain action though compliance and identification, but it is not enough to motivate them to change their perceptions and attitudes toward a sustainable behavior (Turner, 1991; Cialdini and Goldstein, 2004; Harpine, 2015). This result implies that impacts of an environmental policy can be under-estimated if policy-makers do not include social influence in their decisions regarding environmental issues.

Secondly, since network connection promotes pro-environmental behavior, the effectiveness of a conservation policy can be improved only if connections or interactions among individuals are increased. This finding does not support an existing conjecture (De Young et al., 1995), which hypothesizes that increasing interactions between individuals in a large structure can be bad for social conservation behavior. One example validating our results relates to pecuniary and non-pecuniary mechanisms in a spatial coordination game (Banerjee, 2017), consisting of giving agglomeration bonuses to people who interact in an enlarged network. It is shown that these bonuses can enhance coordination towards environmental conservation programs.

Finally, we find that trust in institutions (governments, institutions or leaders) is needed to ensure a positive impact of policy on pro-environmental behavior. It is important because trust of citizens in government can dictate individual behavior in a way that could shape policy design and generate desired policy outcomes. For instance, trust in institutions could help to reduce the risk of free-riding and opportunistic behavior because citizens would be willing to sacrifice some immediate personal benefits (by contributing to common goods, for example) if they have positive expectations of the long-term outcomes of the government's policies (e.g., environmental policies, etc.) (Irwin, 2009). In other words, a successful environmental policy depends largely on trust in institutions through increased transparency, communication strategy, and interaction with populations, etc. (Polman and Slangen, 2008; Zannakis et al., 2015).

In this study, we quantified the strength and relevance of seven groups of social incentives of pro-environmental behavior, which constitutes our main contribution in this study. One issue which has not been fully addressed is the impact of a country's cultural differences on pro-environmental behavior. Our meta-regression partially addressed this issue by using geographical regions and study-specific effects. The coefficient of MEA (i.e., Middle East & Africa) is positive and significant (although at the 10% significance level only), supporting a relatively higher effect compared to Europe (as the base category). However, we admit that our approach cannot satisfactorily address the differences in national cultures. This issue is important enough to be investigated in depth in a future study, in which the general characteristic of a national culture can be captured by using the Hofstede's values, for example, and adopting a previously proven approach (Morren and Grinstein, 2016).

1.4 Methods

1.4.1 Data collection

The dataset in our study was built using the *Web of Science*, *Google Scholar*, *PubMed*, *SagePub*, and *ScienceDirect* databases, as well as some other relevant journal websites. We used keywords to search for related pro-environmental behavior and social incentives.[13][14] With these systematic keyword searches, we collected all the published and unpublished works (1,515 papers). We then did the abstract analysis and excluded all studies that are duplicated, working papers, books, papers without estimation results and papers with only simulation results.

We then put all these papers into our meta-analysis dataset (307 papers). We eliminated all the papers that did not include standard errors, t-values, p-values, confidence intervals or significance levels. For those with t-values, p-values and confidence intervals, we calculated the standard errors. For those that included only the significance level, we computed the standard errors at the reported significance level. For those that reported insignificant results, we computed the standard errors at a 50% significance level (Abrahamse and Steg, 2013; Rosenthal, 1991). After this step, we obtained 92 eligible studies. We continued screening the references of these eligible studies and found an additional 23 eligible records (in 55 relevant studies). An additional update search was conducted in January 2020 with an additional ten eligible studies found (in 29 relevant studies). We

[13] The keywords that we used: “pro-environmental behaviors", “sustainable behaviors", “environmental conservation", “energy conservation", “water conservation", “recycling", “waste recycling", “social incentives", “social intervention", “social influence", “social interaction", “norms", “nudges", “networks", “network structures", “group size", “network size", “network connections", “network density", “leader", “leadership", “social expectation", “social comparison", “peer influence", “trust", “social trust", “institutional trust", “trust in others" or “trust in government" and all possible combinations of these keywords.

[14] We also took both UK and US English into account when performing our keyword searches (e.g., behaviors and behaviours.) and with/without plurals and with Boolean operators (OR, AND, *).

eventually ended-up with 125 studies in the last step. These 125 studies led to 185 observations in our meta-analysis data.[15] A flow diagram of data collection is presented in Figure 1.2. The entire dataset is summarized in Table 1.9, and the descriptive statistics in Table 1.4. The description of study characteristics and the correlation matrix of the social incentives are provided in Tables 1.7 and 1.8.

1.4.2 Dependent variable

Pro-environmental behavior is defined as "behavior that consciously seeks to minimize the negative impact of one's actions on the natural and built world" (Kollmuss and Agyeman, 2002). Pro-environmental behavior in our meta-analysis is measured across 13 different types of pro-environmental behaviors identified from the literature (including pro-environmental behaviors, pro-environmental intentions, energy consumption, energy conservation, water consumption, water conservation, recycling, environmental conservation, environmental program, environmental groups, green consumption, resource extraction, and workplace pro-environmental behaviors). The definitions of dependent variables are provided in Table 1.1. The detailed descriptive statistics of 13 different types of pro-environmental behaviors are reported in Table 1.4. We observed that social incentives are more efficient in promoting pro-environmental intention and green consumption but less efficient in encouraging resource conservation.

The effect sizes are the coefficient estimates in the selected studies. The standard error of the effect sizes are the standard errors of the coefficient estimates. We also calculated the standard error when papers reported only t-values, p-values, confidence intervals or significance levels as previously mentioned. In order to account for heterogeneity in effect sizes across studies, we performed weighted meta-regressions (see details in Meta-regression section). In order to summarize and compare the results from various studies, in addition to the effect sizes included in the weighted regressions, we also used the partial correlation coefficients (PCCs) that are often used in meta-analysis in order to make comparable different studies which are based on different units of measurement (Doucouliagos and Ulubaşoğlu, 2008; Efendic et al., 2011).[16] (Greene, 2003). The standard errors of the PCC are calculated using the formula: $SEpcc_{ij} = \frac{PCC_{ij}}{t_{ij}}$. It should be noted that we did not explore the possibility of using the standardized effect sizes to compare the magnitudes of variable coefficients because it leads to a reduction in the number of observations due to missing data on standard deviations of dependent variables and regressors.

[15] In some papers, the authors used more than one social variables to examine the impacts on pro-environmental behavior.

[16] The PCC can be calculated by the t-statistics of the reported regression estimate t_{ij} and the regression degrees of freedom df_{ij}: $PCC_{ij} = \frac{t_{ij}}{\sqrt{t_{ij}^2 + df_{ij}}}$, where i is the observation i in the study j

1.4.3 Predictor variables

Our predictor variables are seven social incentives dummies, including internal and external social influence, network factors (network size, network connection and leadership), trust in others and trust in institutions. The detailed definitions of these seven social dummies are given in Table 1.2. The descriptive statistics are given in Table 1.4. The results of the descriptive statistics in Table 1.4 suggest that internal social influence and trust in institutions are more effective in general compared to other social incentives for encouraging pro-environmental behavior. The table also shows that the two social incentives commonly studied in the existing literature are internal and external social influence. They accounted for 33.3% and 25.7% of the observations, respectively. Meanwhile, the less commonly used social incentive factor is network size, with only 4.92% of the observations.

1.4.4 Control variables

In order to address the issue of geographical difference or other factors correlated with geographical regions (i.e., regional heterogeneity), we first controlled for the difference between regions (including America, Asia & Pacific, Europe, Middle East & Africa (MEA) and Multiple countries). The list of countries is provided in Table 1.7. Second, we accounted for the heterogeneity across different specifications in terms of control variables (demographic characteristics, education, income, etc.). Third, we included the types of data collection methods that were used in the studies, such as experiment, direct contact, indirect contact and census data. Fourth, we also controlled for types of targeted populations to capture the difference among households, demographic-related population (students, teachers, children or residents), agriculture-related, employed, and other population groups. Finally, we included the study's publication year to capture the time trend of pro-environmental behavior estimates since we observed an increase in effect size (PCC) of the reported pro-environmental behavior across publication year (see Figure 1.3). Variable definitions and descriptive statistics are reported in Table 1.4.

According to the results of Table 1.7, we observed that most of our selected studies were done in the Americas with 37 studies in all. However, a smaller number of studies was conducted in the MEA (Middle East and Africa) countries. On average, only 62 papers in our study controlled for demographic variables (including household size, age or gender), and only some 40 papers controlled for education and income variables (including participants' education levels and income or wages). Most of our studies were conducted using direct contact (including face-to-face interviews, telephone interviews and questionnaires). The most common population used to investigate pro-environmental behavior was households, with 65 studies in all. A smaller number of studies targeted agriculture-related populations such as farmers, fishers or forest users.

1.4.5 Publication bias

Figure 1.4 shows the funnel plot with the regression residuals compared to their corresponding standard errors. This graph is used to access the publication bias (Patterson et al., 2003; Sterne and Egger, 2001)[17]. In the absence of a publication bias, we would expect that the majority of the points would fall inside of the pseudo-confidence region with bounds $\hat{\alpha} \pm 1.96SE$, where $\hat{\alpha}$ is the estimated effect of the mixed-effects model and SE is the corresponding standard error value (Sterne and Egger, 2001). Egger's regression test for funnel plot asymmetry: z-stats = 3.256, p = 0.001 suggests that asymmetry is present in the funnel plot (Egger et al., 1997). This implies that positive estimates may be preferably selected for publication. We should therefore focus on the formal methods of detection of and correction for publication bias. According to the literature, we should regress the estimated effect size on its standard error (Stanley and Doucouliagos, 2010).

$$PCC_{ij} = \beta_0 + \beta_1 SEpcc_{ij} + \epsilon_{ij}, \tag{1.1}$$

where, the coefficient β_0 denotes the overall (average) effect size and β_1 measures the magnitude of the publication bias.

Since Equation (1.1) is heteroskedastic, we apply the weighted least squares with the weights corresponding to the standard errors of the effect size ($1/SEpcc_{ij}$) (Stanley, 2008). In order to control for the dependence of estimates within a study because of multiple estimates per study, we apply the multivariate mixed-effect model (Doucouliagos and Stanley, 2009).

$$\frac{PCC_{ij}}{SEpcc_{ij}} = \beta_1 + \beta_0 \frac{1}{SEpcc_{ij}} + \alpha_j \frac{1}{SEpcc_{ij}} + \frac{\epsilon_{ij}}{SEpcc_{ij}}, \tag{1.2}$$

where, α_j is the study-level random effect and $\mu_{ij} \equiv \frac{\epsilon_{ij}}{SEpcc_{ij}}$ is the estimate-level disturbances.

Estimation results of Equation (1.2) are provided in Table 1.4. The results suggest that the null hypothesis $\beta_1 = 0$ is rejected at the 10% significance level, which means that there is evidence of funnel asymmetry. The positive constant suggests that publication selection is favorable to positive effects. This is also in line with the results of Egger's regression test.

[17]Publication bias is a type of bias that refers to the distortion of empirical data representation on a subject Sterling (1959). For instance, empirical data is distorted because reviewers of scientific journals tend to accept studies with positive significant effects rather than those with negative or insignificant effects

1.4.6 Forest plots and heterogeneity

Figures 1.5-1.8 display the forest plots of effect sizes and their precision.[18] Studies are divided into seven sub-groups of social incentives, i.e. internal social factor (Figure 1.5), external social factor (Figure 1.6), network factors including network size, network connection and leadership (Figure 1.7) and trust, including trust in others and trust in institutions (Figure 1.8). The overall effect size of each sub-group (indicated by a diamond) is also at the bottom of each study subset.

The overall effect size of all studies is first calculated by fitting a random-effect model ($\beta = 0.132, 95\%CI = [0.107, 0.157]$).[19] Viechtbauer (2005).[20] This suggests that social incentives are generally good at encouraging pro-environmental behavior. The Cochran Q-statistic for heterogeneity, which is the weighted deviations related to the summary effect size, is also calculated (Cochran, 1954). The Q-test statistic $Q(df = 184) = 18867.97$ with $p < 0.001$ suggests that heterogeneity exists in our meta-analysis (statistically significant between-study variance).

In order to deal with the heterogeneity of study effect sizes, we applied the moderator analysis with several control variables: differences between regions, differences in specification (presence of demographic, education and income variables), data collection methods (field experiment, direct and indirect method, and census data), types of population (households, employed, agriculture-related, etc.) and publication year.[21] We fit the mixed effect model with restricted maximum likelihood and with the Cochran Q-stat = 7568.11, df=168, $p < 0.001$.[22]

1.4.7 Meta-regression model

We adopted the meta-regression analysis method to further shed light on the "black box" of our meta-analysis results (Havranek and Irsova, 2011; Stanley and Jarrell, 1989). We used the following meta-regression model (where $i = 1, 2, ..., N$ and and $j = 1, 2, ..., M$ stand for observations and studies, respectively):

[18] The forest plot displays the results of several studies with horizontal lines showing the confidence interval for each study and a mark to show the point estimate. It provides visual presentation of the amount of variation between the results of the studies, as well as an estimate of the overall result of all the studies together Freiman et al. (1978).

[19] When the between-study variance is non-zero, the random-effect model for meta-analysis is a well-known approach to account for heterogeneity among studies. The RE model is fitted using the restricted maximum likelihood, which is the most recommendable property

[20] The random effect model: $PCC_{ij} = \beta + \alpha_j + \epsilon_{ij}$, where α_j is the study-specific random effect; ϵ_{ij} is the error term; β is the overall effect size. The regression is weighted by a weight equal to $1/(\tau^2 + v_i)$, where v_i is individual variance and τ^2 is between study-variance, typically preferred to as the amount of heterogeneity (Kalaian and Raudenbush, 1996).

[21] Q-test for moderator: $QM(df = 16) = 40.66, p < 0.001$.

[22] The mixed effect model: $PCC_{ij} = \beta_0 + \beta_1 SEpcc + \sum_{l=1}^{L} \delta_l Z_{ijl} + \alpha_j + \varepsilon_{ij}$, where δ_l is the fixed slope, α_j is the study-specific random effect, ε_{ij} is the error term and β_1 is the publication bias.

$$y_{ij} = \beta_0 + \beta_1 x_{ij} + \sum_{k=1}^{K} \gamma_k SD_{ijk} + \sum_{l}^{L} \delta_l Z_{ijl} + \alpha_j + \varepsilon_{ij}, \tag{1.3}$$

where, y_{ij} is either the effect size coefficient ($Coef_{ij}$) or the partial correlation coefficient (PCC_{ij}) of observation i and study j. Note that x_{ij}, included here to account for the publication bias, corresponds to the standard error of $Coef_{ij}$ (SE) or the standard error of PCC_{ij} ($SEpcc$) depending on the considered regression. A positive (negative) value of β_1 implies a positive (negative) publication bias. SD_{ijk} are the social incentives dummies including internal social influence, external social influence, network size, network connection, leadership, trust in others and trust in institutions (there are K=7 social incentives dummies, network size being the base category). Z_{ijl} is a vector of study-level characteristics (L=18 control variables). In Equation (1.3), the meta-regression coefficients δ_l represent the bias related to L variables including differences between geographical regions, model specifications (demographic, education and income factors), types of study (field experiment or laboratory experiment, etc.), types of population and publication year. A positive (negative) value of δ_l implies a positive (negative) bias. Finally, ε_{ij} is the meta-regression model error.[23]

Because most of the primary literature uses different data-sets, different dependent variables, different types of data collection methods and different sample sizes, it is reasonable to suspect that the meta-regression error is likely to be heteroskedastic. We therefore estimated the model using weighted least squares (WLS) with weights given by $1/e_i$ (e_i is the observation's standard errors).[24]

In summary, we performed the following two regressions with two different dependent variables (PCC or Coef): (1) WLS with weights given by $1/e_i$; and (2) the mixed effect model with weights given by $1/(\tau^2 + v_i)$, where v_i is individual variance and τ^2 is between-study variance, typically preferred as to the amount of heterogeneity (Kalaian and Raudenbush, 1996). Standard errors are calculated using 2000 bootstraps. The estimation results are provided in Table 1.5 and results with all control variables in Table 1.9.

In addition, in order to investigate the impact of the aggregation level of social incentive factors, we organized the seven social incentive groups into three higher aggregated

[23]Note that because of the presence of predictor variable dummies and control variable dummies, the intercept of the meta-regression above (β_0) cannot help to separately identify the overall effect size and the values of the base categories of these groups of dummies.

[24]When the individual standard error is unknown, the model is estimated using weighted least squares (WLS) with weights given by $1/\sqrt{N_i}$ where N_i is the study's sample size. When the individual standard error e_i is known, the heteroskedasticity can also be corrected by weighted least square regression with weights given by $1/e_i$ (Stanley and Jarrell, 1989; Wolf, 1986).

social groups (i.e. social influences, network and trust). We fit the same model in Equation (1.3) with mixed-effects using these three social incentives dummies (the network group being the base category). We fit the model in Equation (1.3) (see Model (6) in Table 1.5). To compare the model of seven social incentives dummies with that of three social incentives dummies, we applied the Wald test with null hypothesis of the equality between the coefficients of internal and external social influence dummies, equality between coefficients of network connection, leadership and network size (i.e., the regression intercept), and equality between trust in institutions and trust in others dummies. The Wald test statistic $\chi^2(4) = 17.61$ with $p = 0.001$ suggests that the model with seven social incentives dummies is preferable.[25] This result implies that our proposed model with seven social incentives dummies is better than the model with three higher-aggregated social incentives dummies. Moreover, in order to compare the magnitude of the impacts of the seven social incentives dummies for Model(4), we calculated the corresponding standardized coefficients as:

$$\tilde{\gamma}_k = \hat{\gamma}_k \frac{s(SD_{ijk})}{s(PCC_{ij})},$$

where $\hat{\gamma}_k$ is the estimated coefficient of predictor k, $s(SD_{ijk})$ and $s(PCC_{ij})$ are the sample standard deviation of the predictor k and the dependent variable (PCC), respectively. Standardized coefficients for other control variables are similarly defined.

[25]The computed statistic of an alternative test (likelihood ratio test) is $\chi^2(4) = 16.92$ with $p = 0.002$, also suggesting that the unrestricted model (i.e., model with seven social incentives dummies) is preferable.

Bibliography

Abrahamse, W. and L. Steg (2013). Social influence approaches to encourage resource conservation: A meta-analysis. *Global Environmental Change 23*(6), 1773–1785.

Abrahamse, W., L. Steg, C. Vlek, and T. Rothengatter (2005). A review of intervention studies aimed at household energy conservation. *Journal of Environmental Psychology 25*(3), 273–291.

Agarwal, S., S. Rengarajan, T. F. Sing, and Y. Yang (2017). Nudges from school children and electricity conservation: Evidence from the "Project Carbon Zero" campaign in Singapore. *Energy Economics 100*(61), 29–41.

Aini, M., S. Chan, and O. Syuhaily (2013). Predictors of technical adoption and behavioural change to transport energy-saving measures in response to climate change. *Energy Policy 61*, 1055–1062.

Ajzen, I. et al. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Processes 50*(2), 179–211.

Alberts, G., Z. Gurguc, P. Koutroumpis, R. Martin, M. Muûls, and T. Napp (2016). Competition and norms: A self-defeating combination? *Energy Policy 96*, 504–523.

Alcock, I., M. P. White, T. Taylor, D. F. Coldwell, M. O. Gribble, K. L. Evans, A. Corner, S. Vardoulakis, and L. E. Fleming (2017). "Green" on the ground but not in the air: Pro-environmental attitudes are related to household behaviours but not discretionary air travel. *Global Environmental Change 42*, 136–147.

Allcott, H. and T. Rogers (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review 104*(10), 3003–3037.

Ando, K., S. Ohnuma, A. Blöbaum, E. Matthies, and J. Sugiura (2010). Determinants of individual and collective pro-environmental behaviors: Comparing Germany and Japan. *Journal of Environmental Information Science 38*(5), 21–32.

Aprile, M. C. and D. Fiorillo (2019). Intrinsic incentives in household waste recycling: The case of Italy in the year 1998. *Journal of Cleaner Production 227*, 98–110.

Arpad, T. (2018). Willing to pay to save the planet? Evaluating support for increased spending on sustainable development and environmentally friendly policies in five countries. *PloS One 13*(11), 1–15.

Asensio, O. I. and M. A. Delmas (2015). Nonprice incentives and energy conservation. *Proceedings of the National Academy of Sciences 112*(6), E510–E515.

Ashenmiller, B. (2011). The effect of bottle laws on income: New empirical results. *American Economic Review 101*(3), 60–64.

Aydin, E., D. Brounen, and N. Kok (2018). Information provision and energy consumption: Evidence from a field experiment. *Energy Economics 71*, 403–410.

Baggio, J. A., N. D. Rollins, I. Pérez, and M. A. Janssen (2015). Irrigation experiments in the lab: Trust, environmental variability, and collective action. *Ecology & Society 20*(4), 12.

Bamberg, S., J. Rees, and S. Seebauer (2015). Collective climate action: Determinants of participation intention in community-based pro-environmental initiatives. *Journal of Environmental Psychology 43*, 155–165.

Banerjee, S. (2017). Improving spatial coordination rates under the agglomeration bonus scheme: A laboratory experiment with a pecuniary and a non-pecuniary mechanism (nudge). *American Journal of Agricultural Economics 100*(1), 172–197.

Barnes, M. L., J. Lynham, K. Kalberg, and P. Leung (2016). Social networks and environmental outcomes. *Proceedings of the National Academy of Sciences 113*(23), 6466–6471.

Bauwens, T. and N. Eyre (2017). Exploring the links between community-based governance and sustainable energy use: Quantitative evidence from flanders. *Ecological Economics 137*, 163–172.

Beitl, C. M. (2014a). Adding environment to the collective action problem: Individuals, civil society, and the mangrove-fishery commons in Ecuador. *World Development 56*, 93–107.

Beitl, C. M. (2014b). Adding environment to the collective action problem: Individuals, civil society, and the mangrove-fishery commons in Ecuador. *World Development 56*, 93–107.

Bekkers, R. and T. Schuyt (2008). And who is your neighbor? Explaining denominational differences in charitable giving and volunteering in the Netherlands. *Review of Religious Research 50*(1), 74–96.

Bénabou, R. and J. Tirole (2006). Incentives and prosocial behavior. *American Economic Review 96*(5), 1652–1678.

Blok, V., R. Wesselink, O. Studynka, and R. Kemp (2015). Encouraging sustainability in the workplace: A survey on the pro-environmental behaviour of university employees. *Journal of Cleaner Production 106*, 55–67.

Bolderdijk, J. W., M. Gorsira, K. Keizer, and L. Steg (2013). Values determine the (in) effectiveness of informational interventions in promoting pro-environmental behavior. *PloS One 8*(12), e83911.

Bolderdijk, J. W., L. Steg, E. S. Geller, P. Lehman, and T. Postmes (2013). Comparing the effectiveness of monetary versus moral motives in environmental campaigning. *Nature Climate Change 3*(4), 413–416.

Brekke, K. A., G. Kipperberg, and K. Nyborg (2010). Social interaction in responsibility ascription: The case of household recycling. *Land Economics 86*(4), 766–784.

Brick, C., D. K. Sherman, and H. S. Kim (2017). "Green to be seen" and "brown to keep down": Visibility moderates the effect of identity on pro-environmental behavior. *Journal of Environmental Psychology 51*, 226–238.

Burn, S. M. (1991). Social psychology and the stimulation of recycling behaviors: The block leader approach. *Journal of Applied Social Psychology 21*(8), 611–629.

Busic-Sontic, A. and F. Fuerst (2018). Does your personality shape your reaction to your neighbours' behaviour? A spatial study of the diffusion of solar panels. *Energy and Buildings 158*, 1275–1285.

Çakır Yıldırım, B. and G. Karaarslan Semiz (2019). Future teachers' sustainable water consumption behavior: A test of the value-belief-norm theory. *Sustainability 11*(6), 1–18.

Carattini, S., A. Baranzini, and J. Roca (2015). Unconventional determinants of greenhouse gas emissions: The role of trust. *Environmental Policy and Governance 25*(4), 243–257.

Cardenas, J. C., J. Stranlund, and C. Willis (2000). Local environmental control and institutional crowding-out. *World Development 28*(10), 1719–1733.

Carfora, V., D. Caso, P. Sparks, and M. Conner (2017). Moderating effects of pro-environmental self-identity on pro-environmental intentions and behaviour: A multi-behaviour study. *Journal of Environmental Psychology 53*, 92–99.

Carrico, A. R. and M. Riemer (2011). Motivating energy conservation in the workplace: An evaluation of the use of group-level feedback and peer education. *Journal of Environmental Psychology 31*(1), 1–13.

Cho, S. and H. Kang (2017). Putting behavior into context: Exploring the contours of social capital influences on environmental behavior. *Environment & Behavior 49*(3), 283–313.

Cialdini, R. B. Influence: The psychology of persuasion (Rev. ed.).

Cialdini, R. B. and N. J. Goldstein (2004). Social influence: Compliance and conformity. *Annual Review of Psychology 55*, 591–621.

Ciocirlan, C. E., D. Gregory-Smith, D. Manika, and V. Wells (2020). Using values, beliefs, and norms to predict conserving behaviors in organizations. *European Management Review*.

Clark, C. F., M. J. Kotchen, and M. R. Moore (2003). Internal and external influences on pro-environmental behavior: Participation in a green electricity program. *Journal of Environmental Psychology 23*(3), 237–246.

Cochard, F., P. N. Van, and M. Willinger (2004). Trusting behavior in a repeated investment game. *Journal of Economic Behavior & Organization 55*(1), 31–44.

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics 10*(1), 101–129.

Collado, S., H. Staats, and P. Sancho (2019). Normative influences on adolescents' self-reported pro-environmental behaviors: The role of parents and friends. *Environment and Behavior 51*(3), 288–314.

Costa, D. L. and M. E. Kahn (2013). Energy conservation "nudges" and environmentalist ideology: Evidence from a randomized residential electricity field experiment. *Journal of the European Economic Association 11*(3), 680–702.

Cotterill, S., P. John, H. Liu, and H. Nomura (2009). Mobilizing citizen effort to enhance environmental outcomes: A randomized controlled trial of a door-to-door recycling campaign. *Journal of Environmental Management 91*(2), 403–410.

D'Adda, G. (2011). Motivation crowding in environmental protection: Evidence from an artefactual field experiment. *Ecological Economics 11*(70), 2083–2097.

De Graaf, N., A. Need, and W. Ultee (2004). Leaving the church in the netherlands: A comprehensive explanation of three empirical regularities. In R. Crockett, A.; O'Leary (Ed.), *Patterns and Processes of Religious Rhange in Modern Industrial Societies: Europe and the United States*. Lewiston, NY: Edwin Mellen Press.

De Young, R., S. Boerschig, S. Carney, A. Dillenbeck, M. Elster, S. Horst, B. Kleiner, and B. Thomson (1995). Recycling in multi-family dwellings: Increasing participation and decreasing contamination. *Population & Environment 16*(3), 253–267.

Dean, A. J., K. S. Fielding, and F. J. Newton (2016). Community knowledge about water: Who has better knowledge and is this associated with water-related behaviors and support for water-related policies? *PloS One 11*(7), 1–18.

Delmas, M. A., M. Fischlein, and O. I. Asensio (2013). Information strategies and energy conservation behavior: A meta-analysis of experimental studies from 1975 to 2012. *Energy Policy 61*, 729–739.

Derksen, L. and J. Gartrell (1993). The social context of recycling. *American Sociological Review 58*(6), 434–442.

Desbureaux, S. (2016). Common resources management and the "Dark Side" of collective action: An impact evaluation for Madagascar's forests. *FAERE Working Paper* (2016.30).

Dietz, T. (2015). Altruism, self-interest, and energy consumption. *Proceedings of the National Academy of Sciences 112*(6), 1654–1655.

Dietz, T. and C. T. Whitley (2018). Environmentalism, norms, and identity. *Proceedings of the National Academy of Sciences 115*(49), 12334–12336.

Dixon, G. N., M. B. Deline, K. McComas, L. Chambliss, and M. Hoffmann (2015). Saving energy at the workplace: The salience of behavioral antecedents and sense of community. *Energy Research & Social Science 6*, 121–127.

Dolnicar, S., A. Hurlimann, and B. Grün (2011). What affects public acceptance of recycled and desalinated water? *Water Research 45*(2), 933–943.

Doran, R., D. Hanss, and T. Øgaard (2017). Can social comparison feedback affect indicators of eco-friendly travel choices? Insights from two online experiments. *Sustainability 9*(2), 1–15.

Doucouliagos, H. and T. D. Stanley (2009). Publication selection bias in minimum-wage research? A meta-regression analysis. *British Journal of Industrial Relations 47*(2), 406–428.

Doucouliagos, H. and M. A. Ulubaşoğlu (2008). Democracy and economic growth: A meta-analysis. *American Journal of Political Science 52*(1), 61–83.

Drescher, M., G. K. Warriner, J. R. Farmer, and B. M. Larson (2017). Private landowners and environmental conservation: A case study of socialpsychological determinants of conservation program participation in Ontario. *Ecology and Society 22*(1), 44.

Dursun, İ., E. Tümer Kabadayı, and A. T. Tuğer (2019). Overcoming the psychological barriers to energy conservation behaviour: The influence of objective and subjective environmental knowledge. *International Journal of Consumer Studies 43*(4), 402–416.

Efendic, A., G. Pugh, and N. Adnett (2011). Institutions and economic performance: A meta-regression analysis. *European Journal of Political Economy 27*(3), 586–599.

Egger, M., G. D. Smith, M. Schneider, and C. Minder (1997). Bias in meta-analysis detected by a simple, graphical test. *BMJ 315*(7109), 629–634.

Elinder, M., S. Escobar, and I. Petré (2017). Consequences of a price incentive on free riding and electric energy consumption. *Proceedings of the National Academy of Sciences 114*(12), 3091–3096.

Fairbrother, M. (2016). Trust and public support for environmental protection in diverse national contexts. *Sociological Science* (3), 359–382.

Fang, W.-T., E. Ng, and M.-C. Chang (2017). Physical outdoor activity versus indoor activity: Their influence on environmental behaviors. *International Journal of Environmental Research and Public Health 14*(7), 797.

Fang, W.-T., E. Ng, C.-M. Wang, and M.-L. Hsu (2017). Normative beliefs, attitudes, and social norms: People reduce waste as an index of social relationships when spending leisure time. *Sustainability 9*(10), 1–18.

Fanghella, V., G. d'Adda, and M. Tavoni (2019). On the use of nudges to affect spillovers in environmental behaviors. *Frontiers in Psychology 10*, 61–61.

Farrow, K., G. Grolleau, and L. Ibanez (2017). Social norms and pro-environmental behavior: A review of the evidence. *Ecological Economics 140*, 1–13.

Fatoki, O. (2019). Hotel employees' pro-environmental behaviour: Effect of leadership behaviour, institutional support and workplace spirituality. *Sustainability 11*(15), 1–15.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations 7*(2), 117–140.

Freiman, J. A., T. C. Chalmers, H. Smith Jr, and R. R. Kuebler (1978). The importance of beta, the type II error and sample size in the design and interpretation of the randomized control trial: Survey of 71 negative trials. *New England Journal of Medicine 299*(13), 690–694.

Frey, B. S. and S. Meier (2004). Social comparisons and pro-social behavior: Testing "conditional cooperation" in a field experiment. *American Economic Review 94*(5), 1717–1722.

Ghazali, E. M., B. Nguyen, D. S. Mutum, and S.-F. Yap (2019). Pro-environmental behaviours and value-belief-norm theory: Assessing unobserved heterogeneity of two ethnic groups. *Sustainability 11*(12), 1–28.

Gilli, M., F. Nicolli, and P. Farinelli (2018). Behavioural attitudes towards waste prevention and recycling. *Ecological Economics 154*(C), 294–305.

Gouu, R. V. (1993). Collective action and network structure. *American Sociological Review 58*(2), 182–196.

Graves, L. M., J. Sarkis, and Q. Zhu (2013). How transformational leadership and employee motivation combine to predict employee proenvironmental behaviors in China. *Journal of Environmental Psychology 35*, 81–91.

Graziano, M. and M. Fiaschetti (2016). The influence of spatial setting and socioeconomic profile in urban areas in the diffusion of residential photovoltaic system systems. In *Implications of North American Energy Self-Sufficiency, 34th USAEE/IAEE North American Conference, Oct 23-26, 2016*. International Association for Energy Economics.

Greene, W. H. (2003). *Econometric Analysis*. Pearson Education India.

Griskevicius, V., J. M. Tybur, and B. Van den Bergh (2010). Going green to be seen: Status, reputation, and conspicuous conservation. *Journal of Personality and Social Psychology 98*(3), 392–404.

Gurevitch, J., J. Koricheva, S. Nakagawa, and G. Stewart (2018). Meta-analysis and the science of research synthesis. *Nature 555*(7695), 175–182.

Han, H. and S. S. Hyun (2018). College youth travelers' eco-purchase behavior and recycling activity while traveling: An examination of gender difference. *Journal of Travel & Tourism Marketing 35*(6), 740–754.

Hao, F., J. L. Michaels, and S. E. Bell (2019). Social capital's influence on environmental concern in China: An analysis of the 2010 Chinese General Social Survey. *Sociological Perspectives 62*(6), 844–864.

Harpine, E. C. (2015). Is intrinsic motivation better than extrinsic motivation? In *Group-Centered Prevention in Mental Health*, pp. 87–107. Springer.

Havranek, T. and Z. Irsova (2011). Estimating vertical spillovers from FDI: Why results vary and what the true effect is. *Journal of International Economics 85*(2), 234–244.

Ho, S. S., Y. Liao, and S. Rosenthal (2015). Applying the theory of planned behavior and media dependency theory: Predictors of public pro-environmental behavioral intentions in Singapore. *Environmental Communication 9*(1), 77–99.

Hopper, J. R. and J. M. Nielsen (1991). Recycling as altruistic behavior: Normative and behavioral strategies to expand participation in a community recycling program. *Environment & Behavior 23*(2), 195–220.

Horne, C. and E. H. Kennedy (2017). The power of social norms for reducing and shifting electricity use. *Energy Policy 107*, 43–52.

Hornsey, M. J., E. A. Harris, P. G. Bain, and K. S. Fielding (2016). Meta-analyses of the determinants and outcomes of belief in climate change. *Nature Climate Change 6*(6), 622–626.

Irwin, K. (2009). Prosocial behavior across cultures: The effects of institutional versus generalized trust. In *Altruism and Prosocial Behavior in Groups*, pp. 165–198. Emerald Group Publishing Limited.

Jachimowicz, J. M., O. P. Hauser, J. D. O'Brien, E. Sherman, and A. D. Galinsky (2018). The critical role of second-order normative beliefs in predicting energy conservation. *Nature Human Behaviour 2*(10), 757–764.

Janmaimool, P. and C. Denpaiboon (2016). Evaluating determinants of rural villagers' engagement in conservation and waste management behaviors based on integrated conceptual framework of pro-environmental behavior. *Life Sciences, Society and Policy 12*(1), 12–31.

Kalaian, H. and S. Raudenbush (1996). A multivariate mixed linear model for meta-analysis. *Psychological Methods 1*(3), 227–235.

Karlin, B., J. F. Zinger, and R. Ford (2015). The effects of feedback on energy conservation: A meta-analysis. *Psychological Bulletin 141*(6), 1205–1227.

Khan, M., D. Jianguo, M. Ali, S. Saleem, and M. Usman (2019). Interrelations between ethical leadership, green psychological climate, and organizational environmental citizenship behavior: A moderated mediation model. *Frontiers in Psychology 10*, 1977–1977.

Kim, A., Y. Kim, K. Han, S. E. Jackson, and R. E. Ployhart (2014). Multilevel influences on voluntary workplace green behavior: Individual differences, leader behavior, and coworker advocacy. *Journal of Management 43*(5), 1335–1358.

Kollmuss, A. and J. Agyeman (2002). Mind the gap: why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research 8*(3), 239–260.

Korkala, E. A., T. T. Hugg, and J. J. Jaakkola (2014). Awareness of climate change and the dietary choices of young adults in Finland: A population-based cross-sectional study. *PloS One 9*(5), e97480.

Kurz, T., M. Linden, and N. Sheehy (2007). Attitudinal and community influences on participation in new curbside recycling initiatives in Northern Ireland. *Environment & Behavior 39*(3), 367–391.

Landon, A. C., G. T. Kyle, and R. A. Kaiser (2017). An augmented norm activation model: The case of residential outdoor water use. *Society & Natural Resources 30*(8), 903–918.

Landon, A. C., K. M. Woosnam, and B. B. Boley (2018). Modeling the psychological antecedents to tourists' pro-sustainable behaviors: An application of the value-belief-norm model. *Journal of Sustainable Tourism 26*(6), 957–972.

Ledyard, J. O. (1995). Public goods: A survey of experimental research. In J. Kagel and A. Roth (Eds.), *Handbook of Experimental Economics*. Princeton: Princeton University Press.

Lee, C.-Y., G. Hochman, S. E. Prince, and D. Ariely (2016). Past actions as self-signals: How acting in a self-interested way influences environmental decision making. *PloS One 11*(7), e0158456.

Lee, K. (2010). The green purchase behavior of hong kong young consumers: The role of peer influence, local environmental involvement, and concrete environmental knowledge. *Journal of International Consumer Marketing 23*(1), 21–44.

Lefebvre, M. and A. Stenger (2020). Short- & long-term effects of monetary and non-monetary incentives to cooperate in public good games: An experiment. *PloS One 15*(1), e0227360.

Leoniak, K. J. and W. Cwalina (2019). The role of normative prompts and norm support cues in promoting light-switching behavior: A field study. *Journal of Environmental Psychology 64*, 1–11.

Lewis, J. D. and A. Weigert (1985). Trust as a social reality. *Social Forces 63*(4), 967–985.

Li, D., C. C. Menassa, and A. Karatas (2017). Energy use behaviors in buildings: Towards an integrated conceptual framework. *Energy Research & Social Science 23*, 97–112.

Liao, C., D. Zhao, S. Zhang, and L. Chen (2018). Determinants and the moderating effect of perceived policy effectiveness on residents' separation intention for rural household solid waste. *International Journal of Environmental Research and Public Health 15*(4), 726.

Lin, S.-P. (2015). Raising public awareness: The role of the household sector in mitigating climate change. *International Journal of Environmental Research and Public Health 12*(10), 13162–13178.

Linder, N., T. Lindahl, and S. Borgström (2018). Using behavioural insights to promote food waste recycling in urban households-evidence from a longitudinal field experiment. *Frontiers in Psychology 9*, 352–352.

Liu, J., H. Qu, D. Huang, G. Chen, X. Yue, X. Zhao, and Z. Liang (2014). The role of social capital in encouraging residents' pro-environmental behaviors in community-based ecotourism. *Tourism Management 41*, 190–201.

Liu, Y., H. Sheng, N. Mundorf, C. Redding, and Y. Ye (2017). Integrating norm activation model and theory of planned behavior to understand sustainable transport behavior: Evidence from China. *International Journal of Environmental Research and Public Health 14*(12), 1593.

Long, J., N. Harré, and Q. D. Atkinson (2014). Understanding change in recycling and littering behavior across a school social network. *American Journal of Community Psychology 53*(3), 462–474.

Lubell, M. and A. Vedlitz (2006). Collective action, environmental activism, and air quality policy. *Political Research Quarterly 59*(1), 149–160.

Macias, T. and K. Williams (2016). Know your neighbors, save the planet: Social capital and the widening wedge of pro-environmental outcomes. *Environment and Behavior 48*(3), 391–420.

Maki, A., A. R. Carrico, K. T. Raimi, H. B. Truelove, B. Araujo, and K. L. Yeung (2019). Meta-analysis of pro-environmental behaviour spillover. *Nature Sustainability 2*(4), 307–315.

McCarty, J. A. and L. Shrum (2001). The influence of individualism, collectivism, and locus of control on environmental beliefs and behavior. *Journal of Public Policy & Marketing 20*(1), 93–104.

Mekonnen, A., R. Bluffstone, et al. (2017). Does community forest collective action promote private tree planting? Evidence from Ethiopia. *International Business Research 10*(5), 86–106.

Meyer, R. and U. Liebe (2010). Are the affluent prepared to pay for the planet? Explaining willingness to pay for public and quasi-private environmental goods in Switzerland. *Population and Environment 32*(1), 42–65.

Miao, L. and W. Wei (2013). Consumers' pro-environmental behavior and the underlying motivations: A comparison between household and hotel settings. *International Journal of Hospitality Management 32*(1), 102–112.

Michaels, L. and Y. Parag (2016). Motivations and barriers to integrating "prosuming" services into the future decentralized electricity grid: Findings from Israel. *Energy Research & Social Science 100*(21), 70–83.

Miller, E. and L. Buys (2008a). The impact of social capital on residential water-affecting behaviors in a drought-prone Australian community. *Society and Natural Resources 21*(3), 244–257.

Miller, E. and L. Buys (2008b). The role of social capital in predicting and promoting "feelings of responsibility" for local environmental issues in an Australian community. *Australasian Journal of Environmental Management 15*(4), 231–240.

Mizobuchi, K. and K. Takeuchi (2013). The influences of financial and non-financial factors on energy-saving behaviour: A field experiment in japan. *Energy Policy 63*, 775–787.

Morren, M. and A. Grinstein (2016). Explaining environmental behavior across borders: A meta-analysis. *Journal of Environmental Psychology 47*, 91–106.

Mzoughi, N. (2011). Farmers adoption of integrated crop protection and organic farming: Do moral and social concerns matter? *Ecological Economics 70*(8), 1536–1545.

Nepal, M., A. K. Bohara, and R. P. Berrens (2007a). The impacts of social networks and household forest conservation efforts in rural Nepal. *Land Economics 83*(2), 174–191.

Nepal, M., A. K. Bohara, and R. P. Berrens (2007b). The impacts of social networks and household forest conservation efforts in rural Nepal. *Land Economics 83*(2), 174–191.

Ng, C. N., R. Y. Wang, and T. Zhao (2013). Joint effects of asymmetric payoff and reciprocity mechanisms on collective cooperation in water sharing interactions: A game theoretic perspective. *PloS One 8*(8), e73793.

Nisa, C. F., J. J. Bélanger, B. M. Schumpe, and D. G. Faller (2019). Meta-analysis of randomised controlled trials testing behavioural interventions to promote household action on climate change. *Nature Communications 10*(1), 1–13.

Nyangena, W. (2008). Social determinants of soil and water conservation in rural Kenya. *Environment, Development and Sustainability 10*(6), 745–767.

Ouvrard, B. and A. Stenger (2017). Nudge in networks. *Cahier du LEF 2017-02*.

Panzone, L. A., A. Ulph, D. J. Zizzo, D. Hilton, and A. Clear (2018). The impact of environmental recall and carbon taxation on the carbon footprint of supermarket shopping. *Journal of Environmental Economics and Management*.

Park, N. and A. Yang (2012). Online environmental community members' intention to participate in environmental activities: An application of the theory of planned behavior in the Chinese context. *Computers in Human Behavior 28*(4), 1298–1306.

Passafaro, P., S. Livi, and A. Kosic (2019). Local norms and the theory of planned behavior: Understanding the effects of spatial proximity on recycling intentions and self-reported behavior. *Frontiers in Psychology 10*, 744.

Patterson, B., S. Thorne, C. Canam, and C. Jillings (2003). Meta-study of qualitative health research: A practical guide to meta-analysis and meta-synthesis. *Nursing in Critical Care 8*(4), 184–184.

Pillemer, K., T. E. Fuller-Rowell, M. Reid, and N. M. Wells (2010). Environmental volunteering and health outcomes over a 20-year period. *The Gerontologist 50*(5), 594–602.

Polman, N. and L. Slangen (2008). Institutional design of agri-environmental contracts in the European Union: The role of trust and social capital. *NJAS - Wageningen Journal of Life Sciences 55*(4), 413–430.

Raineri, N., J. H. Mejía-Morelos, V. Francoeur, and P. Paillé (2016). Employee eco-initiatives and the workplace social exchange network. *European Management Journal 34*(1), 47–58.

Rees, J. H. and S. Bamberg (2014). Climate protection needs societal change: Determinants of intention to participate in collective climate action. *European Journal of Social Psychology 44*(5), 466–473.

Reyhanloo, T., S. Baumgärtner, M. Haeni, S. Quatrini, P. Saner, and E. von Lindern (2018). Private-sector investor's intention and motivation to invest in land degradation neutrality. *PloS One 13*(12), e0208813.

Reynolds-Tylus, T., A. Martinez Gonzalez, and B. L. Quick (2019). The role of choice clustering and descriptive norms in attenuating psychological reactance to water and energy conservation messages. *Environmental Communication 13*(7), 847–863.

Robelia, B. A., C. Greenhow, and L. Burton (2011). Environmental learning in online social networks: Adopting environmentally responsible behaviors. *Environmental Education Research 17*(4), 553–575.

Robertson, J. L. and J. Barling (2013). Greening organizations through leaders' influence on employees' pro-environmental behaviors. *Journal of Organizational Behavior 34*(2), 176–194.

Robertson, J. L. and E. Carleton (2018). Uncovering how and when environmental leadership affects employees' voluntary pro-environmental behavior. *Journal of Leadership & Organizational Studies 25*(2), 197–210.

Rompf, S., C. Kroneberg, and T. Schlösser (2017). Institutional trust and the provision of public goods: When do individual costs matter? The case of recycling. *Rationality & Society 29*(2), 160–178.

Rosenthal, R. (1991). *Meta-Analytic Procedures for Social Research*, Volume 6. Sage.

Sánchez-Medina, A. J., L. Romero-Quintero, and S. Sosa-Cabrera (2014). Environmental management in small and medium-sized companies: An analysis from the perspective of the theory of planned behavior. *PloS One 9*(2), e88504.

Schirmer, J. and F. Dyer (2018). A framework to diagnose factors influencing proenvironmental behaviors in water-sensitive urban design. *Proceedings of the National Academy of Sciences 115*(33), 1–10.

Schultz, P. W., A. Messina, G. Tronu, E. F. Limas, R. Gupta, and M. Estrada (2016). Personalized normative feedback and the moderating role of personal norms: A field experiment to reduce residential water consumption. *Environment and Behavior 48*(5), 686–710.

Schultz, P. W., J. M. Nolan, R. B. Cialdini, N. J. Goldstein, and V. Griskevicius (2007). The constructive, destructive, and reconstructive power of social norms. *Psychological Science 18*(5), 429–434.

Sherkat, D. E. and C. G. Ellison (2007). Structuring the religion-environment connection: Identifying religious influences on environmental concern and activism. *Journal for the Scientific Study of Religion 46*(1), 71–85.

Simpson, B. and R. Willer (2015). Beyond altruism: Sociological foundations of cooperation and prosocial behavior. *Annual Review of Sociology 41*, 43–63.

Sønderskov, K. M. (2008). Environmental group membership, collective action and generalised trust. *Environmental Politics 17*(1), 78–94.

Sønderskov, K. M. (2009). Different goods, different effects: Exploring the effects of generalized social trust in large-N collective action. *Public Choice 140*(1-2), 145–160.

Stanley, T. D. (2008). Meta-regression methods for detecting and estimating empirical effects in the presence of publication selection. *Oxford Bulletin of Economics and Statistics 70*(1), 103–127.

Stanley, T. D. and H. Doucouliagos (2010). Picture this: a simple graph that reveals much ado about research. *Journal of Economic Surveys 24*(1), 170–191.

Stanley and Jarrell (1989). Meta-regression analysis: A quantitative method of literature surveys. *Journal of Economic Surveys 3*(2), 161–170.

Sterling, T. D. (1959). Publication decisions and their possible effects on inferences drawn from tests of significance-or vice versa. *Journal of the American Statistical Association 54*(285), 30–34.

Sterne, J. A. and M. Egger (2001). Funnel plots for detecting bias in meta-analysis: Guidelines on choice of axis. *Journal of Clinical Epidemiology 54*(10), 1046–1055.

Sujata, M., K.-S. Khor, T. Ramayah, and A. P. Teoh (2019). The role of social media on recycling behaviour. *Sustainable Production and Consumption 20*, 365–374.

Terry, D. J., M. A. Hogg, and K. M. White (1999). The theory of planned behaviour: Self-identity, social identity and group norms. *British Journal of Social Psychology 38*(3), 225–244.

Tesfaye, Y., A. Roos, and F. Bohlin (2012a). Attitudes of local people towards collective action for forest management: The case of participatory forest management in Dodola area in the Bale Mountains, Southern Ethiopia. *Biodiversity & Conservation 21*(1), 245–265.

Tesfaye, Y., A. Roos, and F. Bohlin (2012b). Attitudes of local people towards collective action for forest management: The case of participatory forest management in Dodola area in the Bale Mountains, Southern Ethiopia. *Biodiversity and Conservation 21*(1), 245–265.

Testa, F., A. Cosic, and F. Iraldo (2016). Determining factors of curtailment and purchasing energy related behaviours. *Journal of Cleaner Production 5*(112), 3810–3819.

Thaler, R. and C. Sunstein (2008). *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Thøgersen, J. (2013). Psychology: Inducing green behaviour. *Nature Climate Change 3*(2), 100–101.

Thøgersen, J. and F. Olander (2003). Spillover of environment-friendly consumer behaviour. *Journal of Environmental Psychology 23*(3), 225–236.

Tindall, D. B. and G. Piggot (2015). Influence of social ties to environmentalists on public climate change perceptions. *Nature Climate Change 11*(5), 546—-549.

Tucker, P., G. Murney, and J. Lamont (1998). Predicting recycling scheme performance: A process simulation approach. *Journal of Environmental Management 53*(1), 31–48.

Turner, J. C. (1991). *Social Influence*. Thomson Brooks/Cole Publishing Co.

Ünal, A. B., L. Steg, and M. Gorsira (2018). Values versus environmental knowledge as triggers of a process of activation of personal norms for eco-driving. *Environment and Behavior 50*(10), 1092–1118.

Van den Broek, K. L., I. Walker, and C. A. Klöckner (2019). Drivers of energy saving behaviour: The relative influence of intentional, normative, situational and habitual processes. *Energy Policy 132*, 811–819.

Van Der Linden, S. (2015). Intrinsic motivation and pro-environmental behaviour. *Nature Climate Change 5*(7), 612–613.

Van Dijk, W. F. A., A. M. Lokhorst, F. Berendse, and G. R. de Snoo (2015). Collective agri-environment schemes: How can regional environmental cooperatives enhance farmers' intentions for agri-environment schemes? *Land Use Policy 42*, 759–766.

Van Horen, F., A. van der Wal, and A. Grinstein (2018). Green, greener, greenest: Can competition increase sustainable behavior? *Journal of Environmental Psychology 59*, 16–25.

Van Laerhoven, F. (2010). Governing community forests and the challenge of solving two-level collective action dilemmas-a large-N perspective. *Global Environmental Change 20*(3), 539–546.

Videras, J., A. L. Owen, E. Conover, and S. Wu (2012). The influence of social relationships on pro-environment behaviors. *Journal of Environmental Economics & Management 63*(1), 35–50.

Viechtbauer, W. (2005). Bias and efficiency of meta-analytic variance estimators in the random-effects model. *Journal of Educational and Behavioral Statistics 30*(3), 261–293.

Viscusi, W. K., J. Huber, and J. Bell (2014). Private recycling values, social norms, and legal rules. *Revue d'Économie Politique 124*(2), 159–178.

Wakefield, S. E., S. J. Elliott, and D. C. Cole (2007). Social capital, environmental health and collective action: a Hamilton, Ontario case study. *The Canadian Geographer/Le Géographe Canadien 51*(4), 428–443.

Wang, W., J. Jin, R. He, H. Gong, and Y. Tian (2018). Farmers' willingness to pay for health risk reductions of pesticide use in China: A contingent valuation study. *International Journal of Environmental Research and Public Health 15*(4), 625.

Wang, X., K. Zhou, and W. Liu (2018). Value congruence: A study of green transformational leadership and employee green behavior. *Frontiers in Psychology 9*, 1946.

Wasserman, S. and K. Faust (1994). *Social Network Analysis: Methods and Applications*. Cambridge University Press.

Werfel, S. H. (2017). Household behaviour crowds out support for climate change policy when sufficient progress is perceived. *Nature Climate Change 7*, 512—515.

Wesselink, R., V. Blok, and J. Ringersma (2017). Pro-environmental behaviour in the workplace and the role of managers and organisation. *Journal of Cleaner Production 168*, 1679–1687.

Whitmarsh, L. E., P. Haggar, and M. Thomas (2018). Waste reduction behaviors at home, at work, and on holiday: What influences behavioral consistency across contexts? *Frontiers in Psychology 9*, 2447.

Willy, D. K. and K. Holm-Müller (2013). Social influence and collective action effects on farm level soil conservation effort in rural Kenya. *Ecological Economics 90*, 94–103.

Wolf, F. M. (1986). *Meta-analysis: Quantitative Methods for Research Synthesis*, Volume 59. Sage.

Wong, S.-L., C.-C. Hsu, and H.-S. Chen (2018). To buy or not to buy? consumer attitudes and purchase intentions for suboptimal food. *International Journal of Environmental Research and Public Health 15*(7), 1431.

Wynveen, C. J. and S. G. Sutton (2015). Engaging the public in climate change-related pro-environmental behaviors to protect coral reefs: The role of public trust in the management agency. *Marine Policy 53*, 131–140.

Xiao, C. and A. M. McCright (2015). Gender differences in environmental concern: Revisiting the institutional trust hypothesis in the USA. *Environment & Behavior 47*(1), 17–37.

Xu, L., M. Ling, and Y. Wu (2018). Economic incentive and social influence to overcome household waste separation dilemma: A field intervention study. *Waste Management 77*, 522–531.

Yan, X., X. Yong, W. Huang, and Y. Ma (2018). Placebo treatment facilitates social trust and approach behavior. *Proceedings of the National Academy of Sciences 115*(22), 5732–5737.

Yang, W., W. Liu, A. Viña, M.-N. Tuanmu, G. He, T. Dietz, and J. Liu (2013). Nonlinear effects of group size on collective action and resource outcomes. *Proceedings of the National Academy of Sciences 110*(27), 10916–10921.

Yau, Y. (2010). Domestic waste recycling, collective action and economic incentive: The case in Hong Kong. *Waste Management 30*(12), 2440–2447.

Zannakis, M., A. Wallin, and L.-O. Johansson (2015). Political trust and perceptions of the quality of institutional arrangements - how do they influence the public's acceptance of environmental rules. *Environmental Policy & Governance 25*(6), 424–438.

Zaval, L. (2016). Behavioural science: Culture and climate action. *Nature Climate Change 6*(12), 1061–1062.

Zhang, D., G. Huang, X. Yin, and Q. Gong (2015). Residents' waste separation behaviors at the source: Using SEM with the theory of planned behavior in Guangzhou, China. *International Journal of Environmental Research and Public Health 12*(8), 9475–9491.

Zhou, L. and Y. Dai (2019). The influencing factors of haze tolerance in China. *International Journal of Environmental Research and Public Health 16*(2), 287.

Figures

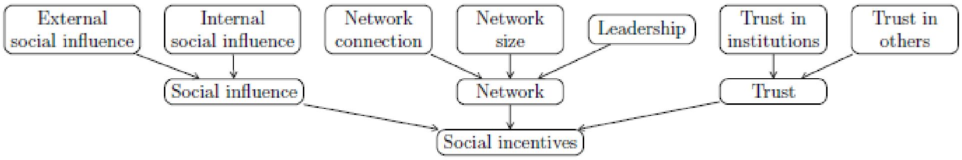


Figure 1.1: Seven groups of social incentives.

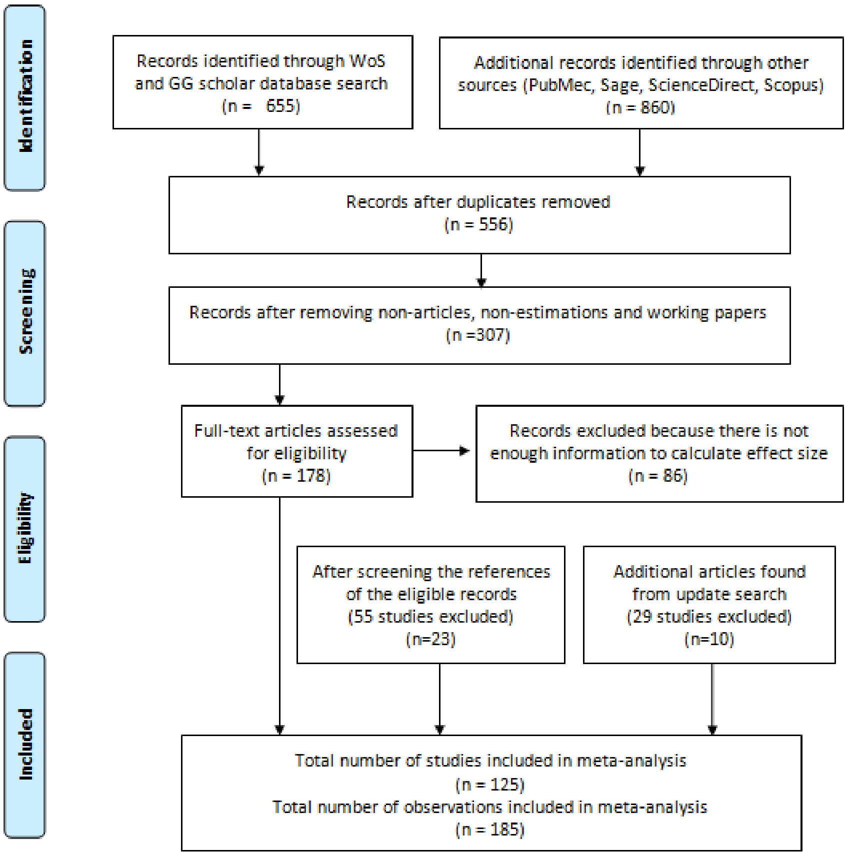


Figure 1.2: Flow diagram of data collection.

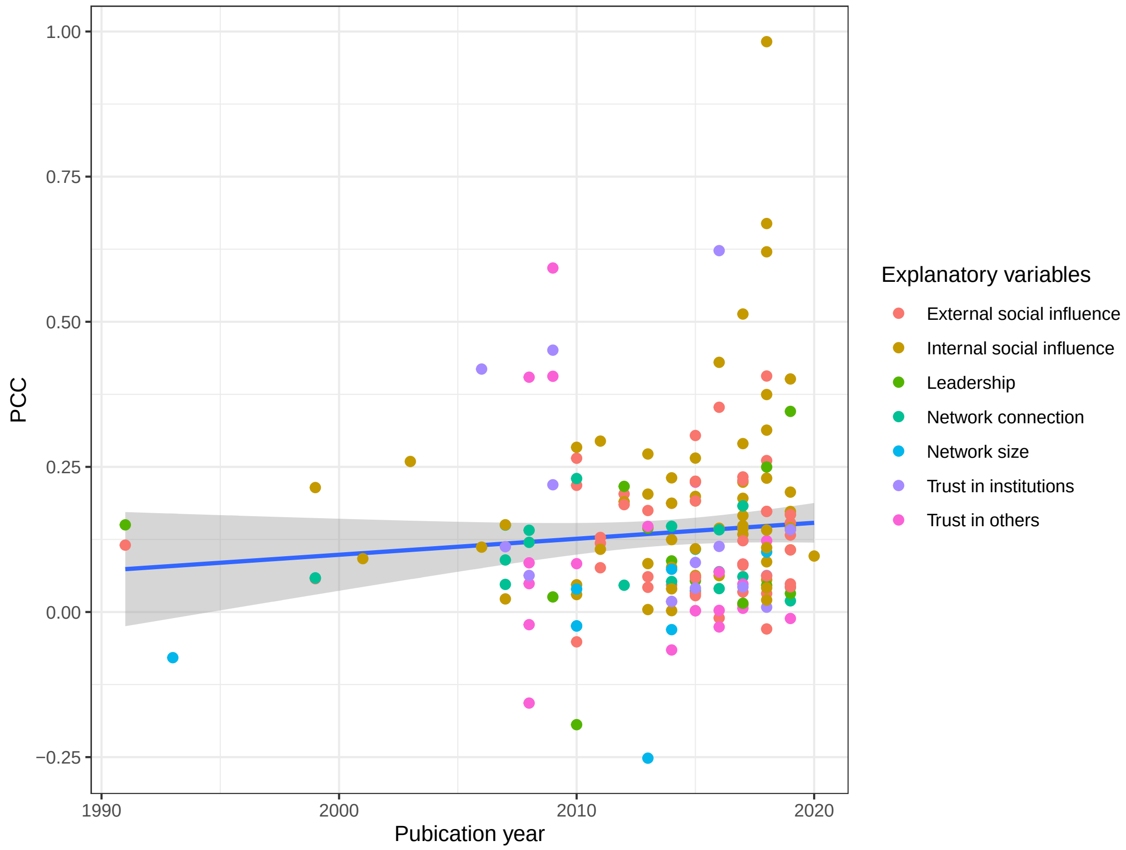


Figure 1.3: Plot of partial correlation coefficient vs. publication year. The line and the shaded area represent the linear fit and the corresponding 95% confidence interval, respectively.

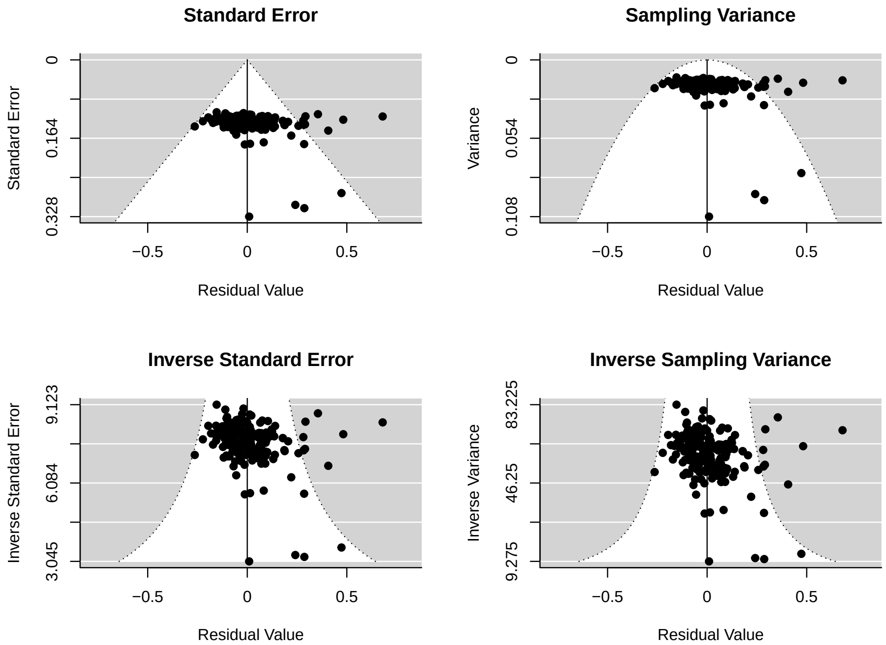


Figure 1.4: Funnel plot for publication bias. Egger's regression test for funnel plot asymmetry: z-stats = 3.256, p = 0.001 which suggests that asymmetry is present in the funnel plot (Egger et al., 1997). The predicted standard error of the funnel plot is the result of the mixed-effect model with seven social dummies and all control variables as moderators.

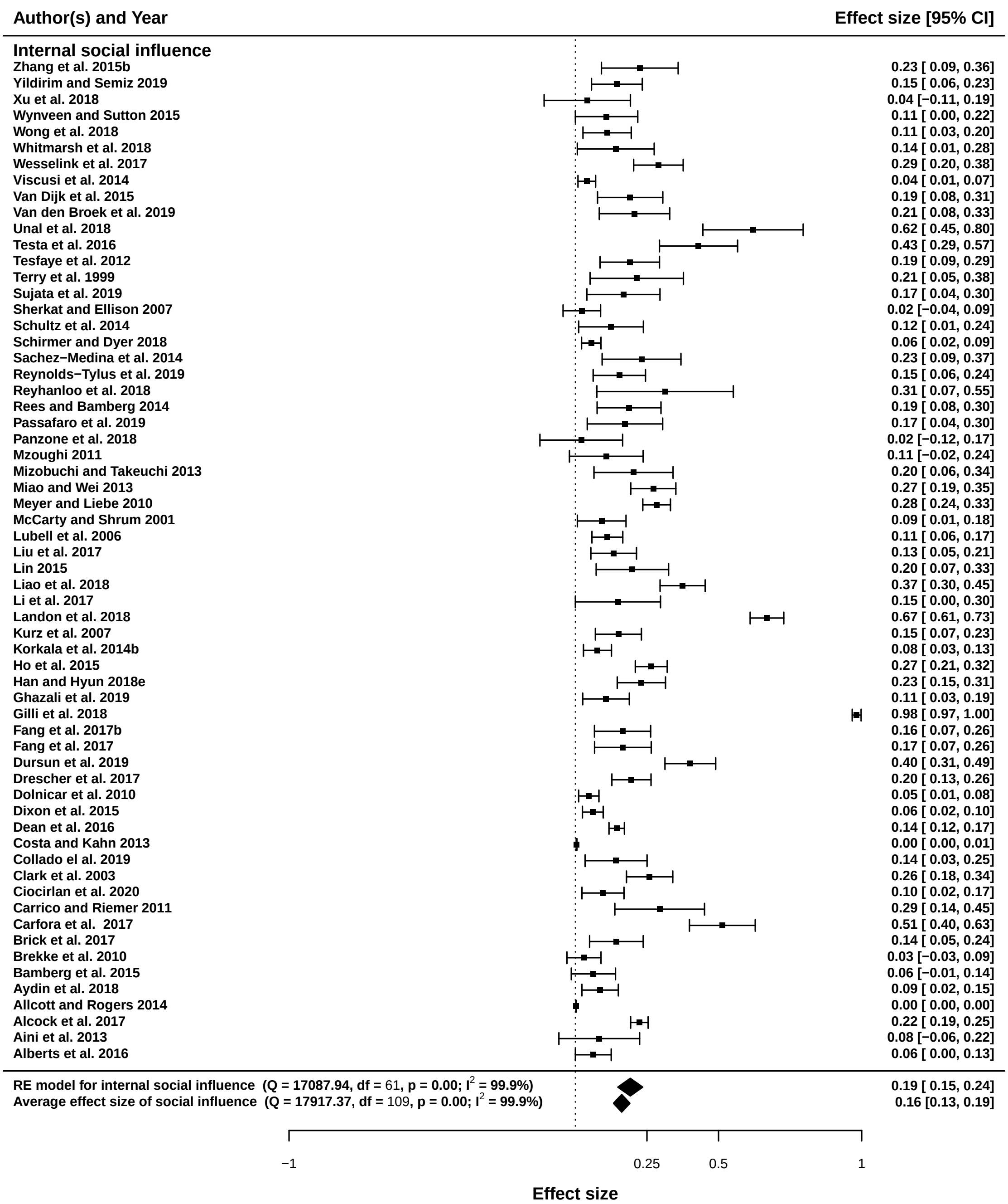


Figure 1.5: Forest plot of internal social influence.

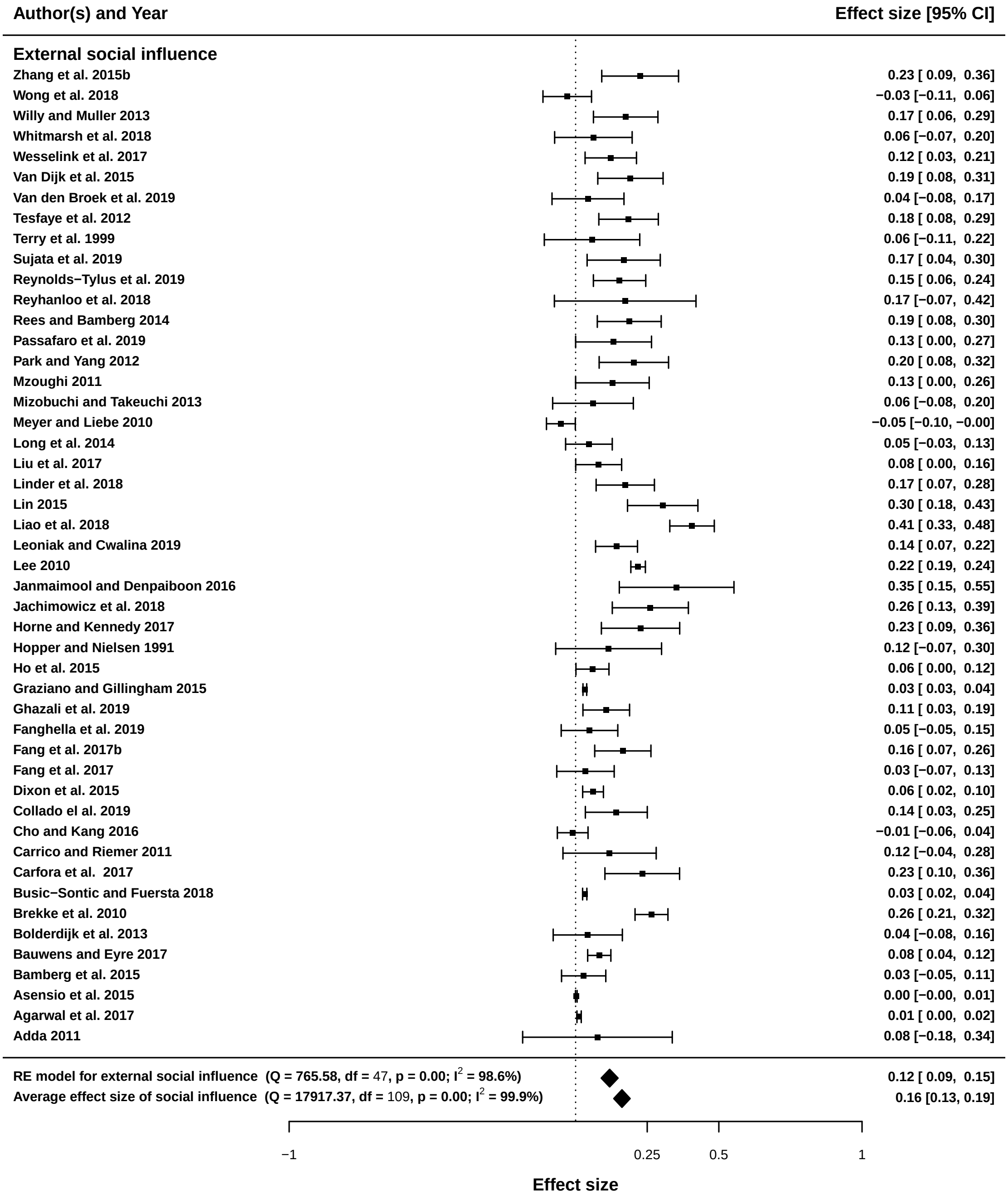


Figure 1.6: Forest plot of external social influence.

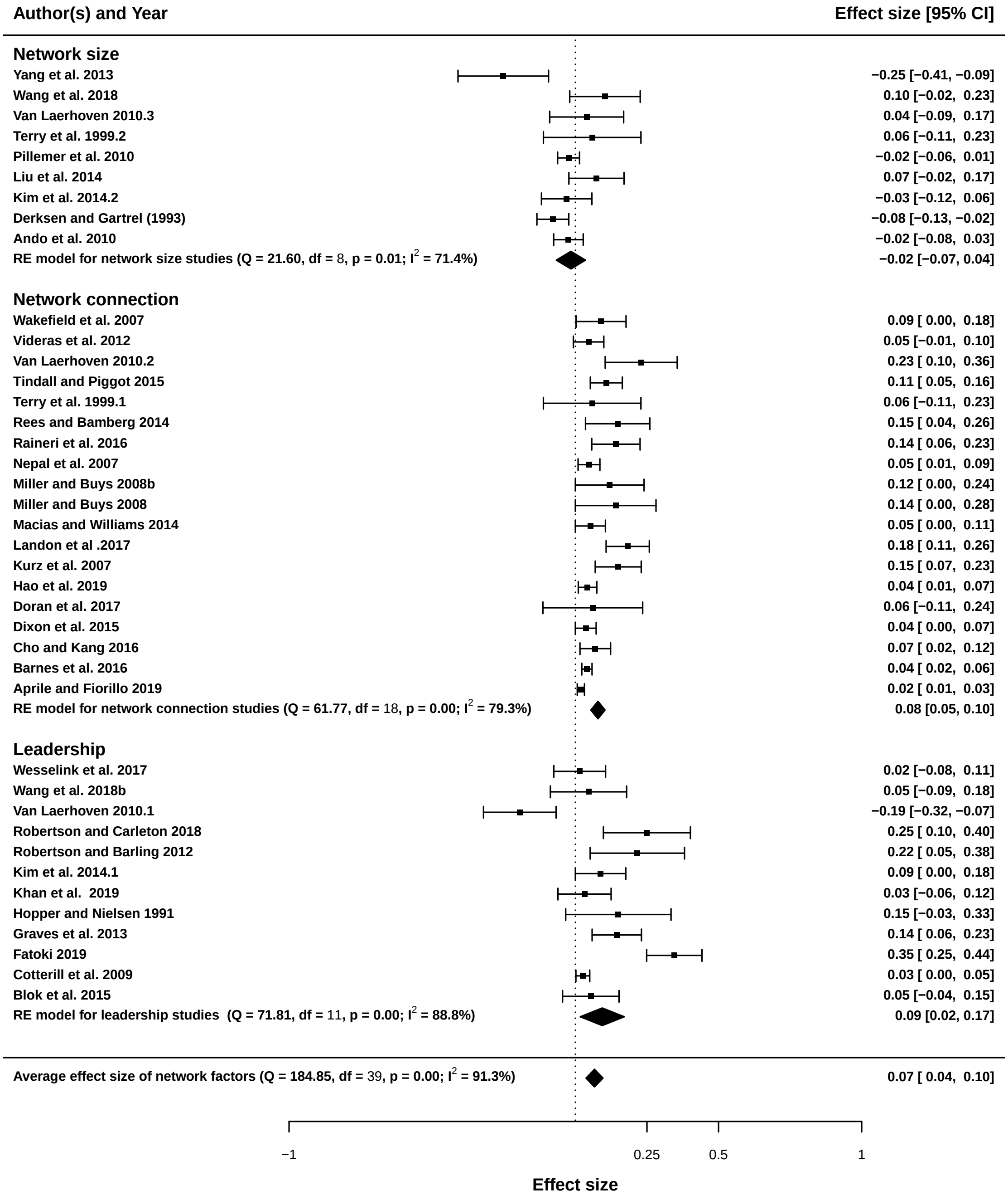


Figure 1.7: Forest plot of network factors.

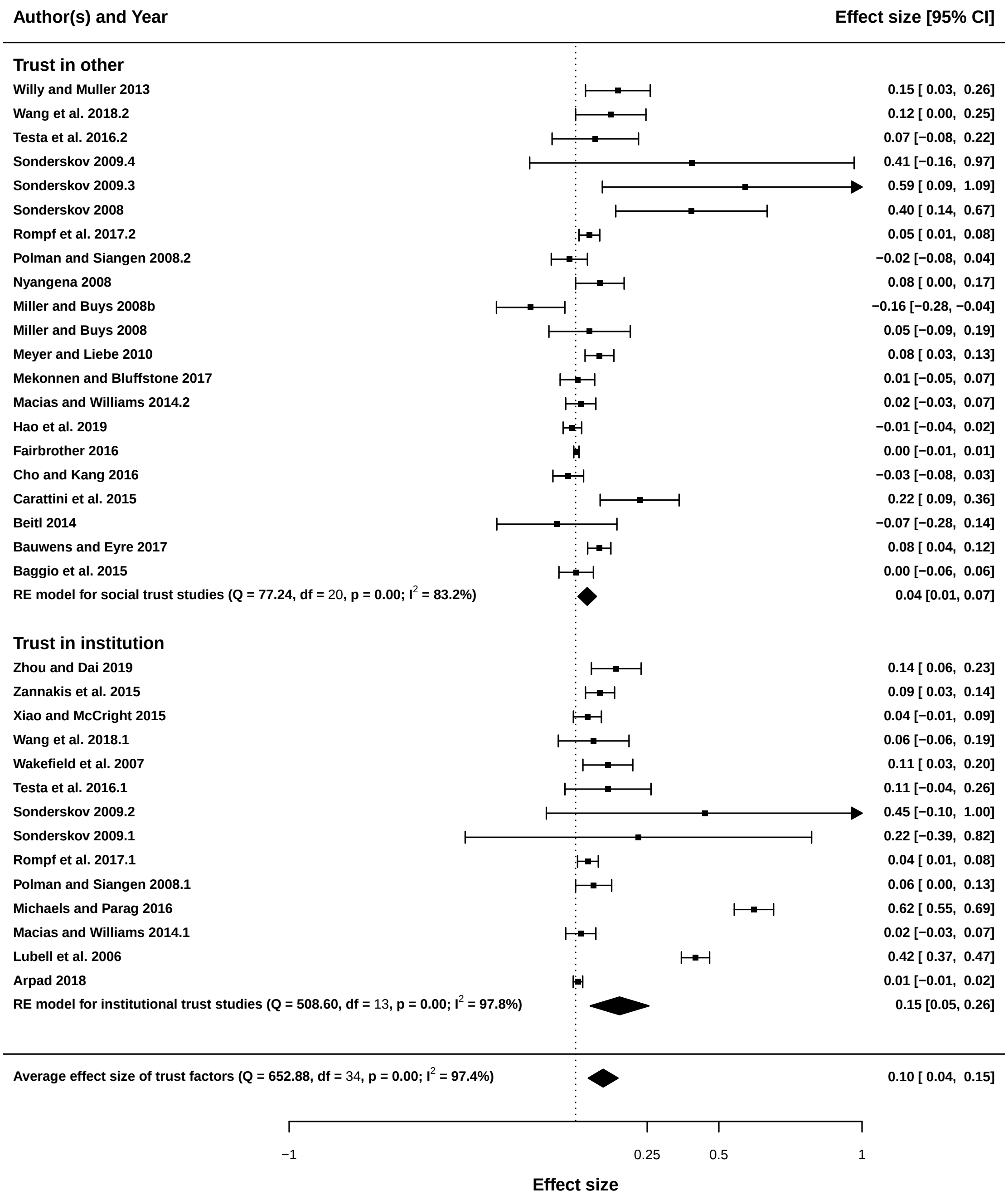


Figure 1.8: Forest plot of trust factors.

Tables

Table 1.1: Definitions of dependent and predictor variables.

Variables used in collected studies		Variables used in our study
Household/individual/self-reported/climate-change pro-environmental actions (behaviors). (Private) environmental actions (behaviors). Collective environmental actions (behaviors).	Pro-environmental behavior	Pro-environmental behaviors
Pro-environmental/behavioral intentions. Environmental efficiency intention. Intention to engage in pro-environmental actions/waste sorting. Intention to reduce car-travel/environmental problems/climate issues.	Pro-environmental intentions	
Percentage change in total energy consumption. Monthly/weekly/daily energy consumption.	Energy consumption[a]	
Self-reported energy conservation/electricity reduction. Energy-saving behaviors/intentions. Use acceptable techniques to conserve energy/installing new solar PV system.	Energy conservation	
Monthly/weekly water use.	Water consumption[a]	
Sustainable water consumption behavior/water conservation. Water-sensitive gardening (car washing) behavior/using recycled (desalinated) water. Soil and water conservation investment.	Water conservation	
Frequency of recycling. Household waste collected/proportion of waste recycled. Number of items recycled. Intention to perform household recycling/recycling intention/waste separation intention.	Recycling	
Number of trees planted on private land/intention to participate in tree planting. Estimated CO2 emission saving. Restriction of intensive practices/adopt organic farming/reduce pesticide use. Regularly engaging in resource/forest monitoring. Soil conservation.	Environmental conservation	
Participation in a solar program. Contribution to a tree planting project (conservation program/environmental protection). Intention to participate in environmental activities.	Environmental programs	
Participation in environmental group (cooperatives).	Environmental groups	
Climate friendly food consumption/green purchasing behaviors.	Green consumption	
Shark bycatch/fishing behaviors.	Resource extraction[a]	
Workplace pro-environmental behaviors. Employee green behavior/organizational environmental behavior.	Workplace environmental behaviors	
Household (energy/electricity/water) consumption report (feedback)/group-level feedback/comparative feedback. Attitude toward pro-environmental behaviors. Fear of social sanctioning/neighbors-judge. “Green to be seen" (visibility) effect. Personal norm/self-identity/environmental identity. Instrinsic motivation/normative motives/willingness to sacrifice for the environment.	Internal social influence	Social influence factors
Information treatment (about other behaviors/environmental messages/environmental movies) Social norms/descriptive norms/subjective norms/injunctive norms/community norms. Installation base (number of solar PV installation in the neighborhood). Peer educator treatment/peer influence. Second-order normative belief.	External social influence	
Eco-network (number of environmentally-minded friends)/number of friends engaged in household recycling. Structural social capital/social network (number of environmental associations participated in). Work group size (number of employees in the work group)/group size/number of users in a forest group.	Network size	Network factors
Network ties to environmental group/environmentalists/belonging to a strong tied network. Bonding social capital (frequency of meetings with friends and relatives)/neighborhood connection/group identification. Community ties/sense of community/community attachment. Frequency of engaging in environmental cooperative activities.	Network connection	
Leadership support (in pro-environmental actions). Block-leadership approach treatment. Leader’s voluntary green workplace behaviors/green transformational leadership/leader’s behaviors. Presence of a group leader.	Leadership	
Interpersonal trust/generalized trust/social trust. Feeling of trust and safety/most people can be trusted. Trust index/level of trustworthiness/level of trust in family and friends.	Trust in others	Trust
Government trust/institutional trust/political trust. Level of trust in public institutions. Trust in government/trust institution in general. Belief in government competence.	Trust in institutions	

Notes: [a] Reverse coded.

Table 1.2: Definitions of predictor variables

Variables used in collected studies		Variables used in our study
Household (energy/electricity/water) consumption report (feedback)/group-level feedback/comparative feedback. Attitude toward pro-environmental behaviors. Fear of social sanctioning/neighbors-judge. "Green to be seen" (visibility) effect. Personal norm/self-identity/environmental identity. Instrinsic motivation/normative motives/willingness to sacrifice for the environment.	Internal social influence	Social influence factors
Information treatment (about other behaviors/environmental messages/environmental movies) Social norms/descriptive norms/subjective norms/injunctive norms/community norms. Installation base (number of solar PV installation in the neighborhood). Peer educator treatment/peer influence. Second-order normative belief.	External social influence	
Eco-network (number of environmentally-minded friends)/number of friends engaged in household recycling. Structural social capital/social network (number of environmental associations participated in). Work group size (number of employees in the work group)/group size/number of users in a forest group.	Network size	Network factors
Network ties to environmental group/environmentalists/belonging to a strong tied network. Bonding social capital (frequency of meetings with friends and relatives)/neighborhood connection/group identification. Community ties/sense of community/community attachment. Frequency of engaging in environmental cooperative activities.	Network connection	
Leadership support (in pro-environmental actions). Block-leadership approach treatment. Leader's voluntary green workplace behaviors/green transformational leadership/leader's behaviors. Presence of a group leader.	Leadership	
Interpersonal trust/generalized trust/social trust. Feeling of trust and safety/most people can be trusted. Trust index/level of trustworthiness/level of trust in family and friends.	Trust in others	Trust
Government trust/institutional trust/political trust. Level of trust in public institutions. Trust in government/trust institution in general. Belief in government competence.	Trust in institutions	

Table 1.3: Test of the publication bias

Variables	Coefficient
Intercept	0.027
	(0.063)
$SEpcc$	2.064*
	(1.186)
Observations	185
Studies	125

Notes: Meta-regression based on multivariate mixed-effect model with PCC as dependent variable and weights = $1/SEpcc$. Standard errors are in parentheses.
*p<0.1; **p<0.05; ***p<0.01.

Table 1.4: A brief summary of the descriptive statistics

	Definition	Mean	SD
Dependent variables			
PCC	Partial correlation coefficient.	0.136	0.151
Coefficient	Effect size coefficient.	1.682	16.392
Predictor variables			
SEpcc	Standard error of the partial correlation coefficient.	0.053	0.043
SE	Standard error of the effect size coefficient.	0.827	5.767
Social influence factors			
Internal social influence	=1 if there is the presence of internal influence, such as personal norms, attitudes, intrinsic motivation or comparative feedback treatments.	0.333	0.472
External social influence	=1 if there is the presence of external social influence, such as norms, peer influence or environmental information treatments.	0.256	0.438
Network factors			
Network size	=1 if there is the presence of environmental network (group) size or friend (neighbor or work) group size.	0.049	0.216
Network connection	=1 if there is the presence of network (social, neighborhood, community or environmental group) ties.	0.103	0.305
Leadership	=1 if there is the presence of a group leader or leadership support in pro-environmental behaviors.	0.065	0.248
Trust			
Trust in institutions	=1 if there is the presence of individual trust in institutions (government, leaders or public/environmental institutions).	0.076	0.266
Trust in others	=1 if there is the presence of individual trust in others (family, friends, neighbors or community).	0.114	0.319
Control variables			
Differences between geographical regions			
America	=1 if study was conducted in the Americas.	0.248	0.433
Asia & Pacific	=1 if study was conducted in Asia and the Pacific.	0.300	0.459
Europe	=1 if study was conducted in Europe.	0.300	0.459
MEA	=1 if study was conducted in the Middle East and Africa.	0.043	0.205
Multiple countries	=1 if study was conducted in more than one country.	0.103	0.305
Difference in model specifications			
Presence of demographic control	=1 if study was controlled for household size, age or gender.	0.502	0.501
Presence of education control	=1 if study was controlled for participants' education level.	0.327	0.470
Presence of income control	=1 if study was controlled for household income, wages or country GDP.	0.360	0.481
Types of data collection method			
Experiment	=1 if study was conducted using field experiment or laboratory experiment.	0.120	0.326
Direct contact	=1 if study was conducted using face-to-face interview, telephone interview or questionnaires.	0.453	0.499
Indirect contact	=1 if study was conducted using online survey or mail (email) survey.	0.311	0.464
Census data	=1 if study was conducted using census data.	0.114	0.319
Types of population			
Employed	=1 if study's population is employers or employees.	0.097	0.297
Demographic-related	=1 if study's population is students, teachers, children or residents.	0.200	0.401
Household	=1 if study's population is households.	0.502	0.501
Agriculture-related	=1 if study's population is farmers, fishers or forest users.	0.081	0.273
Others	=1 if study's population is car-drivers, internet users, investors, landowners, tourists or countries.	0.118	0.324
Publication year	Study's publication year.	22.808	5.263

Notes: The detailed definitions of dependent and explanatory variables are provided in Table 1. The detailed descriptive statistics is given in Table S3 (in the Appendix).

Table 1.5: A brief summary of the meta regression results

	Coef		PCC			
	Weighted least squares	Mixed-effect model	Weighted least squares	Mixed-effect model, 7 social incentives	Standardized coefficient of model (4)	Mixed-effect model, 3 social incentives
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Social influence						0.058***
						(0.017)
Internal social influence	0.218***	0.255***	0.127**	0.149***	0.8436	
	(0.088)	(0.066)	(0.053)	(0.042)		
External social influence	0.090	0.151**	0.079	0.082*	0.4344	
	(0.096)	(0.069)	(0.063)	(0.045)		
Network factors						
Leadership	0.058	0.133	0.075	0.053	0.1504	
	(0.113)	(0.092)	(0.057)	(0.058)		
Network connection	0.085	0.169***	0.018	0.090**	0.3392	
	(0.101)	(0.071)	(0.072)	(0.045)		
Trust						-0.004
						(0.029)
Trust in institutions	0.208	0.223***	0.083	0.108*	0.3371	
	(0.141)	(0.100)	(0.077)	(0.062)		
Trust in others	0.048	0.068	-0.033	0.029	0.1105	
	(0.112)	(0.075)	(0.075)	(0.047)		
Control variables						
Difference between regions						
(Europe as baseline)						
MEA	0.158	0.136*	0.130*	0.118*	0.2853	0.103*
	(0.610)	(0.070)	(0.076)	(0.062)		(0.066)
Presence of demographic variables	-0.211*	-0.069	-0.112***	-0.075**	-0.4488	-0.074**
	(0.141)	(0.063)	(0.028)	(0.034)		(0.035)
Presence of education variables	0.096	0.057	0.093*	0.055*	0.3158	0.054*
	(0.092)	(0.046)	(0.060)	(0.033)		(0.033)
SE (or SEpcc)	1.953**	1.252***	1.058**	1.157***		1.101***
	(0.838)	(0.182)	(0.628)	(0.380)		(0.373)
Intercept	-10.010	-11.941*	-3.458	-5.542		-6.606
	(9.938)	(6.248)	(5.445)	(3.597)		(5.330)
Observations	185	185	185	185		185
Studies	125	125	125	125		125

Notes: Meta-regressions with effect size coefficient or partial correlation coefficient as dependent variables. All the columns are obtained from regressions using seven social incentive groups (network size as the base category), except the last one that is based on the regression using three higher-aggregated social incentive groups (network as the base category). Full estimation results with all control variables are given in Table S5 in the Appendix.
Weighted least squares are estimated with weights equal to 1/SE (or 1/SEpcc). In the multivariate mixed-effect model, the weight is calculated using $1/(\tau^2 + v_i)$, where v_i is individual variance and τ^2 is between study-variance or typically called the amount of heterogeneity (Kalaian and Raudenbush, 1996).
The Wald test of Model in column 4 vs. Model in column 6 is $\chi^2(4) = 17.61$ with $p = 0.001$, suggesting that Model in column 4 is preferable.
Bootstrap standard errors with 2000 replications are in parentheses.
*p<0.1; **p<0.05; ***p<0.01.

Table 1.7: Study characteristics.

Study characteristics	Number of observations	Number of papers
Publication period		
1991-2005	9	5
2006-2010	33	19
2010-2015	58	41
2016-2020	85	62
Data collection method		
Field experiment	19	17
Laboratory experiment	3	3
Face-to-face interview	27	16
Telephone interview	6	3
Online survey	35	22
Mail survey	22	16
Questionnaires	52	36
Census data	21	12
Country by regions		
America	46	37
Canada	5	4
Mexico	1	1
US	38	30
Bolivia	1	1
Ecuador	1	1
Asia & Pacific	55	35
Australia	11	6
China	19	13
Hong Kong	1	1
Japan	2	1
Malaysia	5	3
Nepal	1	1
New Zealand	1	1
Singapore	2	1
South Korea	6	3
Taiwan	8	4
Thailand	1	1
Europe	55	36
Belgium	2	1
Finland	1	1
France	2	1
Germany	6	3
Ireland	2	1
Italy	9	5
Netherlands	9	6
Norway	3	2
Poland	1	1
Spain	3	2
Sweden	1	1
Switzerland	5	2
Turkey	2	2
UK	9	8
Middle East and Africa (MEA)	8	6
Ethiopia	3	2
Israel	1	1
Kenya	3	2
South Africa	1	1
Multiple countries	19	11
Africa, America, Asia	3	1
Europe	9	4
Germany and Japan	1	1
UK, Europe, North Africa	1	1
UK, US, Denmark, and Sweden	2	1
US, Canada	1	1
US, Europe, South Africa, Asia	1	1
US, UK, Romania, Italy	1	1

Table 1.8: Correlation matrix of seven social incentive dummies.

	External social influence	Internal social influence	Trust in institutions	Trust in others	Network size	Network connection	Leadership
External social influence	1.00						
Internal social influence	-0.08	1.00					
	(0.263)						
Trust in institutions	-0.06	-0.04	1.00				
	(0.406)	(0.620)					
Trust in others	-0.07	-0.04	-0.03	1.00			
	(0.327)	(0.559)	(0.664)				
Network size	0.02	0.01	0.01	0.01	1.00		
	(0.755)	(0.852)	(0.890)	(0.870)			
Network connection	-0.12	-0.07	-0.05	-0.06	0.02	1.00	
	(0.116)	(0.350)	(0.488)	(0.413)	(0.794)		
Leadership	-0.06	-0.04	-0.03	-0.03	0.01	-0.05	1.00
	(0.416)	(0.628)	(0.719)	(0.671)	(0.892)	(0.497)	

Notes: The *p*-value of the Pearson correlation coefficient is in parentheses. The Pearson correlation coefficient suggests that there is no multicollinearity in our seven social incentive dummies.

Table 1.9: Summary survey table for meta-analysis of pro-environmental behavior.

Author(Year)	Country	Method	Description	Pro-environmental behavior	Intervention/measurement	Target group	Number of observations
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Internal social influence							
Alberts et al. (2016)Alberts et al. (2016)	UK	Field experiment	Authors investigated the impact of information feedback mechanism on electricity usage at a student resident.	Percentage change in total energy consumption	Weekly home energy report	Students	890
Aini et al. (2013)Aini et al. (2013)	Malaysia	Questionnaires	Authors investigated the relative acceptability of technical adoption and behavioral change to energy-saving transport measures in response to climate change.	Acceptability-technical ("Use energy-efficient car", etc.) (3 items)	Attitude towards energy conservation ("I am willing to make personal sacrifices for the sake of conserving energy", etc.) (4 items)	Employees	201
Alcock et al. (2017)Alcock et al. (2017)	UK	Census data	Authors investigated whether people with pro-environmental value orientations and concerns about the risks of climate change, and those who engage in more pro-environmental household behaviors, would also be more likely to abstain from such voluntary air travel, or at least to fly less far.	Household pro-environmental actions ("conserving energy in their homes, doing recycling", etc.) (in category)	Pro-environmental attitude	Households	3,923
Allcott and Rogers (2014)Allcott and Rogers (2014)	US	Field experiment	Authors investigated the social comparison (which is the household energy report) in the OPOWER program on household monthly energy consumption.	Electricity use (in Kwh/day)	Treatment which is the post-arrival of the household energy report	Households	8,515,691
Aydin et al. (2018)Aydin et al. (2018)	Netherlands	Field experiment	Authors investigated the impact of household consumption feedback on energy consumption through the use of in-home displays during two discrete stages.	Monthly electricity consumption (in log)	Treatment where treated group received weekly energy feedback and information regarding their consumption levels relative to other households	Households	948
Bamberg et al. (2015)Bamberg et al. (2015)	Germany	Face-to-face interview	The author studied the effect of subjective norms, which is when individuals think that their active actions and regular participation are supported by people who are important, on the intention to participate in climate action.	Participation intention in environmental group (in category)	Attitude toward participation ("how do you judge the personal consequences of an active and regular participation in a local environmental group?")	Students	652
Brekke et al. (2010)Brekke et al. (2010)	Norway	Questionnaires	Authors investigated how fear of social sanctioning could affect recycling behavior. The standard error is calculated using the t-stats reported in the paper.	Probability of recycling glass (in dummy (0 or 1))	Fear of social sanctioning	Households	1,104

Brick et al. (2017)Brick et al. (2017)	US	Online survey	Authors studied how environmental identity and social visibility could lead to pro-environmental behavior, which is measured by the frequency of performing pro-environmental behaviors.	Self-reported recurring pro-environmental behavior (frequency of performing 21 pro-environmental behaviors, including air travel, meat and dairy consumption, water conservation and recycling)	"Green to be seen" effect: the interaction between the environmental identity (seeing oneself as pro-environmentalist) and the visibility (one action is visible by others)	Households	437
Carfora et al. (2017)Carfora et al. (2017)	Italy	Census data	The authors studied how subjective norm and self-identity could affect intention to engage in pro-environmental behaviors.	Intention to engage in pro-environmental behaviors (reducing food waste, for example)	Self-identity ("I think of myself as an environmentally-friendly consumer")	Households	220
Carrico and Riemer (2011)Carrico and Riemer (2011)	US	Online survey	Authors studied the impact of different behavioral interventions on monthly electricity consumption in a workplace. The standard deviation is calculated using the reported t-statistics.	Monthly electricity consumption (in Kwh)	Group-level feedback treatment	Employees	145
Ciocirlan et al. (2020)Ciocirlan et al. (2020)	UK	Questionnaires	Authors studied the effects of Value-Belief-Norm (VBN) variables on employee conserving behaviors.	Reducing use (electricity, photocopy, etc.) (5 items)	Personal norms ("I feel a sense of personal obligation to take action at work to stop wasting resources", etc.) (9 items)	Employees	714
Clark et al. (2003)Clark et al. (2003)	US	Mail survey	Authors studied the impact of the altruism scale and NEP score (as internal influence variables) on their green electricity participation decision.	Participation in a solar program	Altruism scale (which is constructed by applying the Schwartz norm-activation model)	Households	557
Collado el al. (2019)Collado et al. (2019)	Spain	Questionnaires	The authors studied how parents' and peers' descriptive and injunctive norms impact students' pro-environmental behaviors.	Environmental behaviors ("I separate paper and cardboard from the rest of the waste", etc.) (8 items)	Personal norm ("because of my own values/principles, I feel obliged to separate paper and cardboard from the rest of the waste")	Students	330
Costa and Kahn (2013)Costa and Kahn (2013)	US	Field experiment	The study aimed to examine how energy conservation "nudges" could help to promote the pro-environmental behavior via the Home Electricity Report (HER) experiment.	Mean daily electricity consumption (Kwh)	Treatment (home energy report - HER treatment)	Households	2,760,175
Dean et al. (2016)Dean et al. (2016)	Australia	Online survey	Authors studied the importance of community knowledge and environmental identity in conserving water source.	Water conservation (use of everyday water-saving strategies with 12 items of 5-point Likert scales)	Environmental identity ("we think of ourselves as an environmentally sustainable household", etc.) (six 5-scale items)	Internet users	5,194
Dixon et al. (2015)Dixon et al. (2015)	US	Online survey	Authors studied the impact of attitudes, subjective norms and behavioral intentions on energy conservation behaviors.	Self-report energy conservation ("turned off lights when not needed", etc.) (6 items)	Attitude ("lowering energy use at work is a good thing") (4 items)	Students	2,919
Dolnicar et al. (2010)Dolnicar et al. (2011)	Australia	Online survey	Authors aimed to identify the factors that are associated with higher levels of public acceptance for recycled and desalinated water.	Stated likelihood of using recycled/desalinated water (10 items)	Attitude towards water conservation ("water conservation is necessary because of water scarcity") (9 items)	Internet users	3,094

Drescher et al. (2017)Drescher et al. (2017)	Canada	Mail survey	Authors aimed to investigate the several established social-psychological determinants on landowner participation in a government-sponsored private land conservation program.	Conservation program participation (yes/no)	Attitude towards the action ("how efficient is the conservation program related to several environmental goals?")	Landowners	800
Dursun et al. (2019)Dursun et al. (2019)	Turkey	Questionnaires	Authors investigated the theoretical and empirical evidence regarding the impeding effects of psychological barriers on individual energy conservation behavior.	Conserving electricity by daily efforts ("turning off the TV immediately if not watching", etc.) (4 items)	Personal norm ("I feel guilty when I waste energy", etc.) (6 items)	Students	415
Fang et al. (2017)Fang et al. (2017)	Taiwan	Questionnaires	The paper studied how descriptive norms could affect the environmental behaviors (sorting waste, outdoor activities, joining an environmental group, etc.).	Environmental behaviors ("I persuade others to sort waste", etc.) (5 items)	Attitude ("I believe participation in environmental protection clubs is useful", etc.) (5 items)	Children	385
Fang et al. (2017b)Fang et al. (2017)	Taiwan	Face-to-face interview	The paper investigated the effects of normative beliefs, attitudes, and social norms on pro-environmental behavioral intentions.	Behavioral intentions ("I will carry my own reusable tableware when I visit theme parks in the future", etc.) (3 items)	Attitude ("It is inconvenient to carry reusable tableware", etc.) (2 items)	Residents	391
Gilli et al. (2018)Gilli et al. (2018)	Italy	Online survey	The paper empirically investigated the relationship between reciprocity (the household declares to prefer a waste management tariff based on the average waste production of the municipality) and food waste recycling behaviors.	Food waste minimization (dummy with minimization = 1)	"Cluster 3" (in which participants are motivated mainly by the intrinsic motivation)	Households	556
Ghazali et al. (2019)Ghazali et al. (2019)	Malaysia	Questionnaires	The paper investigated the impact of Value-Belief-Norm variables on six different types of PEBs (i.e., activist, avoider, green consumer, green passenger, recycler and utility saver).	Green consumption ("use energy-efficient light bulbs", etc.) (14 items)	Personal norm ("feelings of moral obligation for environmental preservation") (8 items)	Residents	581
Han and Hyun (2018)Han and Hyun (2018)	South Korea	Questionnaires	The paper investigated the impact of moral obligation, attitude, and negative affect, and identified the salient role of moral obligation in determining eco-purchase and recycling activities.	Recycling behavior while traveling	Sense of obligation toward eco-friendly behaviors while traveling ("I feel an obligation to act pro-environmentally by choosing eco-friendly activities while traveling to a destination") (3 items)	Students	518
Ho et al. (2015)Ho et al. (2015)	Singapore	Face-face interview	The paper examined the effects of attitude, subjective norms, perceived behavioral control on green-buying behaviors.	Green-buying intentions ("intentions to buy products in refillable packages, products with green labels", etc. in the next 6 months)	Attitude toward pro-environmental behavior ("respondents' belief that engaging in PEBs is enjoyable, beneficial, important, and pleasant")	Households	1,168
Korkala et al. (2014b)Korkala et al. (2014)	Finland	Questionnaires	The author conducted a population-based cross-sectional study to assess if the understanding of climate change, concern over climate change or socio-economic characteristics are reflected in the frequencies of climate-friendly food choices.	Climate friendly food consumption (frequency intake of the climate-friendly food items)	Concern about climate change	Households	1,623
Kurz et al. (2007)Kurz et al. (2007)	Ireland	Mail survey	The author studied how attitudes toward recycling, which has a strong sense of community, affect individuals' actions to participate in recycling.	Recycling participation (monthly bin collection)	Attitudes toward recycling (based on the recycling attitude scale on literature) (7 items)	Households	586

Landon et al. (2018)Landon et al. (2018)	US	Questionnaires	The authors studied the internal attributes that lead tourists to adopt three dimensions of pro-sustainable behavior drawing on the value-belief-norm model.	Eco-behavior (separate recycling from waste, etc.) (4 items)	Personal norm ("as a tourist, I feel morally obligated to do whatever I can to minimize my environmental impact", etc.) (5 items)	Tourists	623
Li et al. (2017)Li et al. (2017)	US	Online Survey	The authors studied the impact of peer pressure on energy conservation in which individuals feel comfortable to explain how to conserve energy to their friends and know that their close friends and colleagues always conserve energy.	Workplace pro-environmental actions ("turning off the office room lights when not in use")	Motivation about pro-environmental actions ("how concerned are you about your personal energy consumption at your office?")	Employees	177
Liao et al. (2018)Liao et al. (2018)	China	Face-face interview	The paper investigated key factors influencing rural residents' separation intention, as well as analyzing the moderating effects of perceived policy effectiveness on the relationship between the determinants and the intention, using survey data of 538 rural residents in the province of Sichuan in China.	Separation Intention (PCA of 3 items)	Attitude ("waste separation is good", etc.) (4 items).	Households	538
Lin (2015)Lin (2015)	Taiwan	Face-face interview	The paper investigated how subjective norms and environmental attitudes affect intention toward efficiency environmental actions	Environmental efficiency intention ("when I replace a lamp, I will purchase an energy-saving one", etc.) (PCA of 4 items)	Environmental attitude ("using energy-saving lamps is not necessary to mitigate global warming", etc.) (4 items).	Households	235
Liu et al. (2017)Liu et al. (2017)	China	Mail survey	The authors proposed an integrated model based on the norm activation model and the theory of planned behavior by combining normative and rational factors to predict individuals' intentions to reduce car use.	Intention to reduce car-travel (Four 7-point scale items)	Attitude towards car-transport reduction (7-point semantic differential scale)	Car-drivers	600
Lubell et al. (2006)Lubell and Vedlitz (2006)	US	Tel. interview	The paper studied how the perceived risk, trust in policy elites, knowledge of the policy problem, and efficacy can help improve the intention to reduce air pollution.	Behavioral intentions (respondent's willingness to perform specific behaviors to reduce air pollution) (five 11-level items)	Personal influence (respondent believes their own actions influence the level of air pollution in their community)	Households	1,326
McCarty and Shrum (2001)McCarty and Shrum (2001)	US	Mail survey	The study investigated the influence of value orientations measured at the individual level (individualism, collectivism, and locus of control) and of economic status on environmental beliefs and behavior.	Recycling behavior ("I recycle newspapers used at home", etc.) (3 items)	Recycling belief ("recycling is important to save natural resources", etc.) (3 items)	Households	534
Meyer and Liebe (2010)Meyer and Liebe (2010)	Switzerland	Census data	The paper took into account various competing economic, psychological and sociological determinants of individuals' willingness to pay (WTP) for both public environmental and quasi-private environmental goods. The standard error is calculated using the reported t-value.	Willingness to pay in environmental protection (yes/no)	Environmental concern (5-point scale question on respondent's environmental attitudes)	Households	1,522
Miao and Wei (2013)Miao and Wei (2013)	US	Mail survey	The authors studied comparison of pro-environmental behavior and the underlying motivations between household and hotel settings.	Recycling behaviors ("I sort trash based on whether it can be recycled", etc.) (3 items)	Normative motives ("feel morally obligated to display pro-environmental behavior")	Households	581

Mizobuchi and Takeuchi (2013)Mizobuchi and Takeuchi (2013)	Japan	Field experiment	The authors studied the impact of comparative feedback with reward on percentage of energy reduction.	Electricity reduction (in Kwh)	Comparative feedback with reward	Households	208
Mzoughi (2011)Mzoughi (2011)	France	Questionnaires	The authors investigated empirically the role of moral and social concerns in farmers' decision to adopt organic farming. The standard error is calculated using the reported significance level.	Adoption of organic farming (in category 1,2,3)	Moral concerns (farmer thinks that do not feel guilty about his own choices is important)	Farmers	243
Panzone et al. (2018)Panzone et al. (2018)	UK	Field experiment	The authors investigated the role of environmental recall and carbon taxation on sustainable food shopping using the online experimental data.	Log amount of estimated CO_2 emission save (gram in 7 days)	Environmental attitudes ("how important is it that you perform environmental behaviors?", etc.) (three 7-scale items)	Students	198
Passafaro et al. (2019)Passafaro et al. (2019)	Italy	Questionnaires	The authors investigated the role of local norm on intention to perform household waste recycling.	Behavioral intentions (during the next month, I intend to engage in household waste recycling) (two 6-scale items)	Attitude toward household waste recycling (one 6-scale items)	Students	222
Rees and Bamberg (2014)Rees and Bamberg (2014)	Germany	Mail Survey	The paper investigated the concept of social norms into the social identity model of collective action, to investigate the determinants of individuals' collective climate action intention. The standard error is calculated using the reported significance level.	Participation intention (three 5-scale items)	Group-based emotion ("I feel guilty about how we humans are treating the environment", etc.) (5-scale items)	Students	302
Reyhanloo et al. (2018)Reyhanloo et al. (2018)	Switzerland	Online survey	The authors studied the factors that motivate the private-sector investors' intention and motivation to invest in land degradation neutrality. The standard error is calculated using the reported significant level.	Intention to invest in land degradation neutrality (yes/no)	Attitudes ("To the best of my knowledge, I think Land Degradation Neutrality is a promising solution to counteract land degradation in the long-term") (four 6-scale items)	Investors	68
Reynolds-Tylus et al. (2019)Reynolds-Tylus et al. (2019)	US	Online survey	The authors studied the impact of choice clustering and descriptive norms on water and energy conservation.	Intention ("I intend to take steps to conserve my [energy/water] use on a daily basis")	Attitudes (taking steps to conserve my [energy/water] use would be beneficial to me)	Internet users	455
Sachez-Medina et al. (2014)Sánchez-Medina et al. (2014)	Spain	Face-face interview	The objective of this paper are to clarify the attitudes of the managers of Canarian small and medium-sized companies about taking environmental measures, and try to demonstrate whether there is a relationship between the proposed factors and the intention to take these measures.	Intention to perform pro-environmental behaviors	Attitude toward pro-environmental behaviors	Employers	201
Schirmer and Dyer (2018)Schirmer and Dyer (2018)	Australia	Face-face interview	The objective of this paper are to investigate the factors that influence adoption of pro-environmental behaviors in promoting water-sensitive gardening behavior	Water-sensitive gardening behavior (mean of four measures: composting, mulching, raking, raking-blowing to street)	Attitude toward pro-environmental behaviors (belief own actions affect water quality)	Households	3,334

Schultz et al. (2014)Schultz et al. (2016)	US	Field experiment	The author studied the role of social norms messages in promoting water conservation.	Weekly water consumption	"Aligned norms feedback" treatment	Households	301
Sherkat and Ellison (2007)Sherkat and Ellison (2007)	US	Census data	The author studied the connection between religion and environmental concern and activism.	Private Environmental Behaviors (frequency of engaging in recycling, reducing automobile use and buying food products grown without pesticides and chemicals)	Willingness to sacrifice for the environment ("pay much higher prices in order to protect the environment", etc.) (three 5-scale items)	Households	908
Sujata et al. (2019)Sujata et al. (2019)	Malaysia	Online survey	The author studied the moderating role of governmental and non-governmental organizations (NGOs) in translating recycling intention.	Recycling intention ("I'd rather use old plastic/durable bags for shopping than new ones", etc.) (4 items)	Attitude ("I believe that my recycling behavior will help reduce pollution", etc.) (5 items)	Internet users	233
Terry et al. (1999)Terry et al. (1999)	Australia	Questionnaires	The authors investigated how norms, self-identity and social identity could affect the intention to perform recycling behaviors.	Intention to perform household recycling	Attitude toward recycling	Households	143
Tesfaye et al. (2012)Tesfaye et al. (2012b)	Ethiopia	Questionnaires	The authors investigated the attitude and intention of households towards participating in collective forest management (tree planting) activity.	Intention to participate in tree planting	Attitude towards participating in planting	Households	349
Testa et al. (2016)Testa et al. (2016)	Italy	Mail survey	The paper explored the influence of personal capabilities and moral norms, along with trust in information on energy saving actions provided by different entities on two energy saving behaviors.	Energy-saving behaviors (4 items)	Personal norm ("I have a responsibility to contribute to environmental preservation by using energy saving products", etc.) (4 items)	Students	198
Van den Broek et al. (2019)Van den Broek et al. (2019)	Multiple countries	Online survey	The paper investigated the relative influence of intentional, normative, situational and habitual processes on energy saving behavior.	Energy-saving intention (2 items)	Personal norm ("due to values important to me, I feel obliged to use as little energy as possible")	Internet users	247
Unal et al. (2018)Ünal et al. (2018)	Netherlands	Face-face interview	The paper explored whether personal norms are important predictors of eco-driving.	Intention to eco-drive (3 items)	Personal norm ("I feel morally obliged to drive in a fuel-efficient way", etc.) (2 items)	Households	83
Van Dijk et al. (2015)Van Dijk et al. (2015)	Netherlands	Mail survey	The authors studied the effectiveness of agri-environment schemes (AES) in enhancing biodiversity on farmland and motivating farmers toward environmentally-friendly practices.	Intention to participate in ditch bank/meadow bird management	Attitude toward ditch bank/meadow bird management ("I think that ditch bank/meadow bird management is positive")	Farmers	297
Viscusi et al. (2014)Viscusi et al. (2014)	US	Questionnaires	The paper studied how the legal and regulatory environment is strongly related to average county recycling rates and private perceptions of neighbors' attitudes toward recycling.	Number of cans and papers recycled	Neighbor would be upset (yes/no)	Households	4,058
Wesselink et al. (2017)Wesselink et al. (2017)	Netherlands	Online survey	The study examined the role of organization and managers and workplace pro-environmental behaviors.	Pro-environmental behavior in the workplace	Attitude toward pro-environmental behaviors	Employees	479

Whitmarsh et al. (2018)Whitmarsh et al. (2018)	UK	Online Survey	The paper examined the predictors of recycling and waste reduction habits across the workplace, home and holiday contexts, and examined whether consistency across contexts is a function of pro-environmental identity.	Proportion of waste recycled	Attitude ("I believe that recycling at home benefits(1) me, (2) my local area and (3) then environment, respectively")	Employees	213
Wong et al. (2018)Wong et al. (2018)	Taiwan	Questionnaires	The paper examined the extended Theory of Planned Behavior (TPB) research model, which includes environmental concern and sensory appeal to predict consumers' purchase intention to suboptimal foods	Purchase intention (suboptimal food)	Attitude ("buying suboptimal food is a good idea", etc.) (4 items)	Households	539
Wynveen and Sutton (2015)Wynveen and Sutton (2015)	US	Tel. interview	The paper examined the role of stakeholder trust in a management agency, as a source of information about climate change, in climate-change-pro-environmental behaviors.	Climate-change-pro-environmental behaviors ("using energy efficient products, recycling", etc.) (20 items)	Personal norm ("I feel guilty about the ways I negatively impact the health of the marine park", etc.) (8 items)	Households	324
Xu et al. (2018)Xu et al. (2018)	China	Field experiment	The study tested the effects of economic incentive and social influence, which are theoretically considered as two general solutions to the domestic waste separation dilemma.	Household waste separation (separate recyclables, etc.) (4 items)	Personal norm ("due to my personal values/principles for environmental protection I feel obliged to separate waste in my everyday life", etc.) (2 items)	Households	188
Yıldırım and Semiz (2019)Çakır Yıldırım and Karaarslan Semiz (2019)	Turkey	Questionnaires	The study investigated pre-service teachers' sustainable water consumption behaviors using the Value-Belief-Norm theory.	Sustainable water consumption behavior (I purposefully select products that allow me to conserve water) (4 items)	Personal norm ("I feel personally obliged to save as much water as possible", etc.) (8 items)	Teachers	482
Zhang et al. (2015b)Zhang et al. (2015)	China	Questionnaires	The study examined factors associated with waste separation behaviors by analyzing responses to questionnaires distributed in Guangzhou, China.	Separation intention ("I am glad to participate in the government waste separation plan", etc.) (3 items)	Attitude ("waste separation can create a better community environment") (3 items)	Households	208
External social influence							
Adda (2011)D'Adda (2011)	Bolivia	Laboratory experiment	Authors estimated how motivation, crowding and social image affect environmental conservation decisions	Contribution to a tree planting project (0-50 Bolivianos)	Public treatment (announce the contribution to others in the group)	Households	63
Agarwal et al. (2017)Agarwal et al. (2017)	US	Field experiment	Authors estimated how the "zero carbon" project in schools (school children nudges/information nudges) affects electricity consumption.	Monthly electricity consumption (in Kwh)	The treatment variable (electricity conservation messages from children to homes)	Households	69,257
Asensio et al. (2015)Asensio and Delmas (2015)	US	Field experiment	Authors investigate how nonprice-based environment and health messaging can have substantial and economically meaningful reductions in demand at the household level. The result used in the meta-analysis is the estimation of the treatment variable "health group" (which is an information nudge treatment) on household energy consumption.	Weekly household energy consumption (in Kwh)	The treatment "health group" (which is an information nudge treatment)	Households	490,994

Bamberg et al. (2015)Bamberg et al. (2015)	Germany	Face-to-face interview	The author studied the effect of subjective norms, which is when individuals think that their active actions and regular participation are supported by people who are important, on the intention to participate in climate action.	Participation intention in environmental group (in category)	Subjective norm ("would people, who are important to you, support your active and regular participation in a local TT group?"	Students	652
Bauwens and Eyre (2017)Bauwens and Eyre (2017)	Belgium	Online Survey	Authors empirically addressed the question of selection in community-based energy projects in terms of energy use, focusing on the case of renewable energy cooperatives.	Participation in a renewable energy cooperative	Pro-environmental orientation (whether the respondent perceives him or herself as someone concerned with the environment)	Households	2,357
Bolderdijk et al. (2013)Bolderdijk et al. (2013)	Dutch	Laboratory experiment	Authors investigated how informational incentives (informing the public about the environmental consequences of their actions via environmental movies) should result in increased pro-environmental intentions and behavior.	Pro-environmental intentions ("I'm planning to reuse water bottles, etc.)	Information treatment which is the environmental movie.	Students	266
Brekke et al. (2010)Brekke et al. (2010)	Norway	Questionnaires	Authors investigated how common glass recycling could affect household recycling behavior. The standard error is calculated using the t-stats reported in the paper.	Probability of recycling glass	"Glass recycling is common"	Households	1,104
Busic-Sontic and Fuersta (2018)Busic-Sontic and Fuerst (2018)	UK	Census data	Authors investigated the impact of geographical concentrations of personality traits on peer effects for adoption of solar photovoltaic (PV) systems. The result used in the meta-analysis is the estimation of the variable "installed base" (number of solar PV installations per dwelling in a postcode 3 months prior to adoption), which is used to capture the peer effect on the number of solar PV adoptions.	Number of new solar PV installations per dwelling	"Installed base" (number of solar PV installations per dwelling in a postcode 3 months prior to adoption)	Households	69,930
Carfora et al. (2017)Carfora et al. (2017)	Italy	Census data	The authors studied how subjective norm and self-identity could affect the intention to engage in pro-environmental behaviors.	Intention to engage in pro-environmental behaviors (reducing food waste, for example)	Subjective norm ("I think that most people who are important to me would approve with my reducing the amount of food that they throw away from my household over the next week")	Households	220
Carrico and Riemer (2011)Carrico and Riemer (2011)	US	Online survey	Authors studied the impact of different behavioral interventions on monthly electricity consumption in a workplace. The standard error is calculated using the reported t-statistics.	Monthly electricity consumption (in Kwh)	Peer education treatment (sending volunteers as peer educators within departments)	Employees	145
Cho and Kang (2016)Cho and Kang (2017)	South Korea	Tel. interview	The authors studied the impact of norms, which is when community members work with each other and share the same values, on private environmental actions (donating money or volunteering to participate in an environmental group).	Private environmental behavior ("prefer to buy environmentally-friendly products", etc.) (three 4-level items)	Norms ("I care about what my neighbors think about my behaviors", etc.) (three 4-level items)	Households	1,348

Collado el al. (2019)Collado et al. (2019)	Spain	Questionnaires	The authors studied how parents' and peers' descriptive and injunctive norms impact students' pro-environmental behaviors.	Environmental behaviors ("I separate paper and cardboard from the rest of the waste", etc.) (8 items)	Best friend's descriptive norm ("my best friend separates paper and cardboard from the rest of the waste")	Students	330
Dixon et al. (2015)Dixon et al. (2015)	US	Online survey	Authors studied the impact of attitudes, subjective norms and behavioral intentions on energy conservation behaviors.	Self-report energy conservation ("turned off lights when not needed", etc.) (6 items)	Descriptive norm ("the people I work with, whose opinions I value,are concerned about their energy use") (3 items)	Students	2,919
Fang et al. (2017)Fang et al. (2017)	Taiwan	Questionnaires	The paper studied how descriptive norms could affect the environmental behaviors (sorting waste, outdoor activities, joining environmental group, etc.).	Environmental behaviors ("I persuade others to sort waste", etc.) (5 items)	Subjective norm ("people I know want me to save water", etc.) (5 items)	Children	385
Fang et al. (2017b)Fang et al. (2017)	Taiwan	Face-to-face interview	The paper investigated the effects of normative beliefs, attitudes and social norms on pro-environmental behavioral intentions	Behavioral intentions ("I will carry my own reusable tableware when I visit theme parks in the future", etc.) (3 items)	Social norms ("I am willing to follow the strategy that the government employed to limit the use of disposable tableware.", etc.) (5 items)	Residents	391
Fanghella et al. (2019)Fanghella et al. (2019)	UK	Online Survey	Authors studied how participants' environmental self-identity and social information leads to increased donations to an UK environmental organization.	Donation to UK WWF environmental organization (0-1)	Social information treatment (in which the participants receive information that "last week, we conducted a similar survey on Prolific: participants were willing to donate on average 40% of their bonus to WWF UK.")	Internet users	397
Ghazali et al. (2019)Ghazali et al. (2019)	Malaysia	Questionnaires	The paper investigated the impact of Value-Belief-Norm variables on six different types of PEBs (i.e., activist, avoider, green consumer, green passenger, recycler and utility saver).	Green consumption ("use energy-efficient light bulbs", etc.) (14 items)	Social norm ("most people who are important to me think I should purchase green products in place of conventional, non-green products", etc.) (7 items)	Residents	581
Graziano and Gillingham (2015) Graziano and Fiaschetti (2016)	US	Census data	The paper reported that the average number of solar PV installations in the neighborhood has an impact on the adoption of photovoltaic (PV) systems.	Number of PV installations	Installed base (previous installation in the neighborhood)	Households	90,090
Ho et al. (2015)Ho et al. (2015)	Singapore	Face-face interview	The paper examined the effects of attitude, subjective norms and perceived behavioral control on green-buying behaviors.	Green-buying intentions ("intentions to buy products in refillable packages, products with green labels, etc. in the next 6 months")	Subjective norm ("family members, close friends, and the general public engage in PEBs on a regular basis")	Households	1,168
Hopper and Nielse (1991)Hopper and Nielsen (1991)	US	Field experiment	The author investigated how social norms, which is when friends and neighbors expect recycling or they expect their friends and neighbors to recycle, has an impact on recycling behavior.	Recycling score (number of times each household recycled)	Information treatment (receiving informational brochure about the curbside recycling program)	Households	240

Horne and Kennedy (2017)Horne and Kennedy (2017)	US	Online survey	The paper studied whether participants used their emissions-related behavior as a signal to others to affect participants' reduction in emissions.	Carbon emission reduction responses (0-10)	Visibility (information was visible to the other players) with control for the respondents' liberal ideology.	Households	199
Jachimowicz et al. (2018)Jachimowicz et al. (2018)	US	Field experiment	The paper explored the role of first and second-order belief in household energy saving.	Percentage of monthly energy saving	Second-order normative belief ("the majority of neighbors (or community) thinks that reducing household energy contributes to saving the environment"	Households	211
Janmaimool and Denpaiboon (2016)Janmaimool and Denpaiboon (2016)	Thailand	Questionnaires	The paper evaluated determinants of villagers' engagement in pro-environmental behavior (PEB) which is the involvement in reusing and recycling products and waste reduction behavior by using potential predictors including a community norm, environmental knowledge, sense of obligation and self-efficacy and psychosocial characteristics.	Frequency of engagement in pro-environmental activities	Community norm ("your neighbors pay attention to issues related to ecological conservation and environmental protection").	Households	102
Lee (2010)Lee (2010)	Hong Kong	Questionnaires	The paper examined the possible contextual and individual factors that affect green purchase behavior in young consumers in Hong Kong.	Green purchasing behaviors (PCA of 4 items)	Peer influence ("how much do your friends tell you about things that are related to environmental protection?", etc.) (2 items).	Students	5,682
Leoniak and Cwalina (2019)Leoniak and Cwalina (2019)	Poland	Field experiment	The paper examined the impact of descriptive norm messages as well as the role of congruent or conflicting normative cues on promoting light-switching behavior.	Light-witching in unoccupied room (yes/no)	Descriptive norm message ("the vast majority of people turn off the light when leaving a restroom").	Students	710
Liao et al. (2018)Liao et al. (2018)	China	Face-face interview	The paper investigated key factors influencing rural residents' separation intention, as well as analyzing the moderating effects of perceived policy effectiveness on the relationship between the determinants and the intention, using survey data of 538 rural residents in the province of Sichuan in China.	Separation intention (PCA of 3 items)	Subjective norm ("most people who are important to me think I should separate household waste", etc.) (3 items).	Households	538
Lin (2015)Lin (2015)	Taiwan	Face-face interview	The paper investigated how subjective norms and environmental attitudes affect intentions toward efficiency environmental actions	Environmental efficiency intention (when I replace a lamp, I will purchase an energy-saving one, etc.) (PCA of 4 items)	Subjective norm ("when I buy a lamp, the person whom I concern will remind me to purchase an energy saving one", etc.) (4 items).	Households	235
Linder et al. (2018)Linder et al. (2018)	Germany	Field experiment	The paper investigated whether an information intervention can be effective in promoting recycling of food waste in an urban area	Household waste collected (in Kg)	Information intervention (information leaflet send to households with the information "Join your neighbors on Hovmästargatan, recycle your food waste").	Households	364

Liu et al. (2017)Liu et al. (2017)	China	Mail survey	The authors proposed an integrated model based on the norm activation model and the theory of planned behavior by combining normative and rational factors to predict individuals' intentions to reduce car use.	Intention to reduce car-travel (Four 7-point scale items)	Subjective norm ("most of the people important to me think that I should reduce car-transport", etc.) (three 7 point scale items)	Car-drivers	600
Long et al. (2014)Long et al. (2014)	New Zealand	Field experiment	The author investigated how perceived friends' norms for littering affect students' littering behaviors in a New Zealand high school community.	Recycling behavior ("I put my bottles and cans into the school recycling bins")	Perceiving friends' recycling norms ("my friends put their bottles and cans into the school recycling bins")	Students	600
Meyer and Liebe (2010)Meyer and Liebe (2010)	Switzerland	Census data	The paper took into account various competing economic, psychological and sociological determinants of individuals' willingness to pay (WTP) for both public environmental and quasi-private environmental goods. The standard error is calculated using the reported t-value.	Willingness to pay in environmental protection (yes/no)	Conditional cooperation ("Regardless of what other people do, I personally try as much as possible to behave in a way that is environmentally aware")	Households	1,522
Mizobuchi and Takeuchi (2013)Mizobuchi and Takeuchi (2013)	Japan	Field experiment	The authors studied the impact of comparative feedback with reward on percentage of energy reduction.	Electricity reduction (in Kwh)	Social norm (5-point Likert scale)	Households	208
Mzoughi (2011)Mzoughi (2011)	France	Questionnaires	The authors empirically investigated the role of moral and social concerns in farmers' decisions to adopt organic farming. The standard error is calculated using the reported significance level.	Adoption of organic farming (in category 1,2,3)	Variable "Show" which is "farmer thinks that showing one's environmental commitment to others is important"	Farmers	243
Park and Yang (2012)Park and Yang (2012)	China	Online survey	The author studied the factors associated with online environmental community members' intentions to participate in environmental activities in the Chinese context.	Behavioral intention to participate in environmental activities (5 items)	Subjective norm ("most people important to me think that I should participate in environmental activities") (3 items)	Internet users	260
Passafaro et al. (2019)Passafaro et al. (2019)	Italy	Questionnaires	The authors investigated the role of local norm on intention to perform household waste recycling.	Behavioral intentions ("during the next month, I intend to adopt household waste recycling") (two 6-scale items)	Subjective norm ("most of the people who are important to me think that I should recycle household waste") (Four 6-scale items)	Students	222
Rees and Bamberg (2014)Rees and Bamberg (2014)	Germany	Mail Survey	The paper investigated the concept of social norms in the social identity model of collective actions, to investigate the determinants of individuals' collective climate action intention. The standard error is calculated using the reported significance level.	Participation intention (three 5-scale items)	Participation norm (injunctive and descriptive norm)	Students	302
Reyhanloo et al. (2018)Reyhanloo et al. (2018)	Switzerland	Online survey	The authors investigated how the subjective norm could affect investment in land degradation. The standard error is calculated using the reported significance level.	Intention to invest in land degradation neutrality (yes/no)	Subjective norm	Investors	68

Reynolds-Tylus et al. (2019)Reynolds-Tylus et al. (2019)	US	Online survey	The authors studied the impact of choice clustering and descriptive norms on water and energy conservation.	Intention ("I intend to take steps to conserve my [energy/water] use on a daily basis")	Perceived descriptive norm ("most of the people I know take steps each day to conserve their [energy/water] use")	Internet users	455
Sujata et al. (2019)Sujata et al. (2019)	Malaysia	Online survey	The author studied the moderating role of governmental and non-governmental organizations (NGOs) in translating recycling intentions.	Recycling intention ("I'd rather use old plastic/durable bags for shopping than new ones", etc.) (4 items)	Social norm ("my neighbors expect me to engage in recycling behavior", etc.) (3 items)	Internet users	233
Terry et al. (1999)Terry et al. (1999)	Australia	Questionnaires	The authors investigated how norms, self-identity and social identity could affect the intention to perform recycling behaviors.	Intention to perform household recycling	Subjective norm	Households	143
Tesfaye et al. (2012)Tesfaye et al. (2012b)	Ethiopia	Questionnaires	The authors investigated the attitude and intention of households towards participating in collective forest management (tree planting) activity.	Intention to participate in tree planting	Subjective norm	Households	349
Van den Broek et al. (2019)Van den Broek et al. (2019)	Multiple countries	Online survey	The paper investigated the relative influence of intentional, normative, situational and habitual processes on energy saving behavior.	Energy saving intention (2 items)	Social norm ("people who are important to me support me when I curtail my energy use") (2 items)	Internet users	247
Van Dijk et al. (2015)Van Dijk et al. (2015)	Netherlands	Mail survey	The authors studied the effectiveness of agri-environment schemes (AES) in enhancing biodiversity on farmland and motivating farmers toward environmental-friendly practices.	Intention to participate in ditch bank management/meadow bird management	Subjective norm ("most people who are important to me think it is important that I carry out ditch bank management/meadow bird management")	Farmers	297
Wesselink et al. (2017)Wesselink et al. (2017)	Netherlands	Online survey	The study examined the role of organization and managers and workplace pro-environmental behaviors.	Pro-environmental behavior in the workplace	Subjective norms	Employees	479
Whitmarsh et al. (2018)Whitmarsh et al. (2018)	UK	Online Survey	The paper examined the predictors of recycling and waste reduction habits across the workplace, home and holiday contexts, and examined whether consistency across contexts is a function of pro-environmental identity.	Proportion of waste recycled	Social norm ("most of my friends and family recycle at home")	Employees	213
Willy and Muller (2013)Willy and Holm-Müller (2013)	Kenya	Face-face interview	The author studied the effects of social influence and participation in collective action initiatives on soil conservation efforts among smallholder farmers in Lake Naivasha basin, Kenya.	Number of soil conservation practices implemented	Subjective norm ("would adopt a technology because those important to me think I should") (yes/no)	Households	307
Wong et al. (2018)Wong et al. (2018)	Taiwan	Questionnaires	The paper examined the extended Theory of Planned Behavior (TPB) research model, which includes environmental concern and sensory appeal to predict consumers' purchase intentions in relation to suboptimal foods	Purchase intention (suboptimal food)	Subjective norm ("most people, important to me, think that I should buy suboptimal food") (3 items)	Households	539

Zhang et al. (2015b)Zhang et al. (2015)	China	Questionnaires	The study examined factors associated with waste separation behaviors by analyzing responses to questionnaires distributed in Guangzhou, China.	Separation intention ("I am glad to engage in the government waste separation plan", etc.) (3 items)	Subjective norm ("my neighbors expect me to separate waste") (3 items)	Households	208
Network size							
Ando et al. (2010)Ando et al. (2010)	Multiple countries	Mail survey	The authors investigated how social factors such as the number of networks and subjective norms affect collective pro-environmental behaviors.	Reducing behaviors (not buying throwaway products)	Eco-net (number of environmentally-minded friends who the respondents see less than once a month) (2 questions)	Residents	1,456
Derksen and Gartrel (1993)Derksen and Gartrell (1993)	Canada	Field experiment	The authors investigated how people who have access to a structured recycling program (sending a blue box for recycling to households) have a higher level of recycling.	Number of items recycled	Single-family dwelling (yes/no)	Households	1,245
Kim (2014)Kim et al. (2014)	South Korea	Questionnaires	The author studied the impact of motivation in work groups and social responsibility on voluntary green behavior in the workplace.	Workplace green advocacy ("I work with my group members to create a more environmentally-friendly workplace", etc.) (3 items)	Work group size (number of employees in the work group)	Employees	496
Liu et al. (2014)Liu et al. (2014)	China	Questionnaires	The author studied the role of social capital in encouraging residents' pro-environmental behaviors.	Pro-environmental behaviors ("I'll take actions to protect the environment", etc.) (3 items)	Structural social capital (number of associations participated in, etc.) (3 items)	Households	420
Pillemer et al. (2010)Pillemer et al. (2010)	US	Questionnaires	The paper tested the hypothesis that volunteering in environmental organizations in midlife is associated with greater physical activity and improved mental and physical health over a 20-year period.	Environmental volunteering and physical activity	Social isolation (number of close friends or relatives they saw at least once a month)	Households	2,630
Terry et al. (1999)Terry et al. (1999)	Australia	Questionnaires	The authors investigated how norms, self-identity and social identity could affect the intention to perform recycling behaviors.	Intention to perform household recycling	How many of your friends and peers would engage in household recycling?	Households	143
Van Laerhoven (2010)Van Laerhoven (2010)	Multiple countries	Census data	The author studied the effective local forest governance regime using a large-N cross-national dataset.	Monitoring ("do forest user groups engage in regular monitoring?") (yes/no)	Number of user group members (log)	Forest groups	240
Wang et al. (2018)Wang et al. (2018)	China	Face-face interview	The paper aimed to explore the factors that influence Chinese farmers' willingness to pay for health risk reductions of pesticide use by applying the contingent valuation method.	WTP to reduce pesticide use (yes/no)	Social network (number of organizations the farmers belong to)	Farmers	261
Yang et al. (2013)Yang et al. (2013)	China	Face-to-face	The authors studied the effect of group size, which is the ratio of parcel size to group size in a forest parcel, on forest-cover changes.	Total labor input for resource monitoring per year	Group size (the number of households monitoring a single forest parcel) (in quadratics)	Households	156
Network connections							

Aprile and Fiorillo (2019)Aprile and Fiorillo (2019)	Italy	Census data	Authors studied the relationship between environmental concern and household waste collection, controlling for social capital.	Recycling (householder recycles at least one material among paper, plastic, glass, aluminium and food waste) (yes/no)	Bonding social capital (frequency of meetings with friends and relatives every day or at least twice a week)	Households	24,474
Barnes et al. (2016)Barnes et al. (2016)	Hawaii	Questionnaires	Authors used information-sharing networks among large-scale commercial tuna fishers to examine how social networks relate to shark bycatch, a global environmental issue.	Shark bycatch (shark (any species) per fishing set)	'V-A network (network with more links and strong ties)	Fishers	12,060
Cho and Kang (2016)Cho and Kang (2017)	South Korea	Telephone interview	The author studied the impact of community ties, which is when community members frequently interact with their neighbors and look after each other, on private environmental actions (donating money or volunteering to participate in an environmental group).	Private environmental behavior (prefer to buy environmentally-friendly products, etc.) (three 4-level items)	Community ties ("I think people in this neighborhood look after each other", etc.) (three 4-level items)	Households	1,348
Dixon et al. (2015)Dixon et al. (2015)	US	Online survey	Authors studied the impact of attitudes, subjective norms and behavioral intentions on energy conservation behaviors.	Self-report energy conservation (turned off lights when not needed, etc.) (6 items)	Sense of community ("feel a sense of community with the people they work with") (6 items)	Students	2,919
Doran et al. (2017)Doran et al. (2017)	Norway	Mail survey	The author studied whether the choosing eco-friendly travel choices is sensitive to in-group identification.	Behavioral intentions (how much of the paper you use do you recycle?, etc.)	In-group identification (degree to which they identified with members of that group)	Students	134
Hao et al. (2019)Hao et al. (2019)	China	Face-face interview	The study examined the ways in which social capital (measured through social networks and trust) influences people's environmental concern in China.	Pro-environmental behavior (six 4-level items)	Social capital (frequency of socializing with relatives and friends) (5-level item)	Households	3,672
Kurz et al. (2007)Kurz et al. (2007)	Ireland	Mail survey	The author studied how living in an area that has a strong sense of community, affects individuals' actions to participate in recycling.	Recycling participation (monthly bin collection)	Sense of community (frequency of socializing with relatives and friends) (8 items)	Households	586
Landon et al. (2017)Landon et al. (2017)	US	Mail survey	The authors tested an augmented Schwartz's Norm Activation Model (NAM) that incorporates community attachment to understand the factors that lead to the development of moral obligations to conserve water and with residential outdoor water use.	Monthly water use	Community attachment ("overall, I am attached to my community") (2 items)	Household	654
Macias and Williams (2014)Macias and Williams (2016)	US	Census data	The author investigated the relationship of social capital and pro-environmental behaviors.	Reduce household energy consumption (4-level item)	Social evenings with neighbors (1 = never and 7 = several times a week)	Households	1,417
Miller and Buys (2008)Miller and Buys (2008a)	Australia	Face-face interview	The authors studied how fostering social capital, environmental responsibility, and socio-demographic lifestyle may encourage people to work together on environmental and sustainable initiatives in a drought-prone Australian community.	Car washing on lawn (yes/no)	Neighborhood connections (5 items)	Households	209

Miller and Buys (2008b)Miller and Buys (2008b)	Australia	Questionnaires	The authors investigated how eight distinct elements of social capital predict a "feeling of responsibility" for local environmental issues in a drought-prone community.	Responsibility for water conservation and environmental conservation	Neighborhood connections	Households	276
Nepal et al. (2007)Nepal et al. (2007b)	Nepal	Census data	The paper investigated the links between the strength and type of social networks and private forest conservation activity in rural Nepal.	Number of trees planted on own land	Social network indices related to forest group (network density between respondent and forest users)	Households	2,657
Raineri et al. (2016)Raineri et al. (2016)	Mexico	Questionnaires	The paper tested whether a model of taking initiatives based on the workplace social exchange network may influence suggestions for constructive change toward the environment.	Eco-initiatives (I voluntarily carry out environmental actions and initiatives in my daily work activities) (3 items)	Affective commitment to the work group ("I really feel like I am a part of this work group") (3 items)	Students	535
Rees and Bamberg (2014)Rees and Bamberg (2014)	Germany	Mail Survey	The paper investigated the concept of social norms in the social identity model of collective action, to investigate the determinants of individuals' collective climate action intentions. The standard error is calculated using the reported significance level.	Participation intention (three 5-scale items)	Sense of community ("It is very important to me that there is a sense of community in my neighborhood")	Students	302
Terry et al. (1999)Terry et al. (1999)	Australia	Questionnaires	The authors investigated how norms, self-identity and social identity could affect the intention to perform recycling behaviors.	Intention to perform household recycling	How much do you identify with your group of friends and peers, as well as feelings of belonging to the group?	Households	143
Tindall and Piggot (2015)Tindall and Piggot (2015)	Canada	Questionnaires	The authors studied the influence of social ties, which is the total number of ENGOs (Environmental Non Government Organizations) connections, on the public's concern about climate.	Plan to deal with climate change (Do you personally plan to do anything in response to climate change?) (yes/no)	Network ties to ENGOs (total number of ENGOs (from a list of 15 organizations) to which the respondent held personal ties)	Households	1,227
Van Laerhoven (2010)Van Laerhoven (2010)	Multiple countries	Census data	The author studied the effective local forest governance regime using a large-N cross-national dataset.	Monitoring ("do forest user groups engage in regular monitoring?") (yes/no)	How many cooperative activities other than forest governance do user group members engage in (0-6)?	Forest groups	240
Videras et al. (2012)Videras et al. (2012)	US	Online survey	The authors investigated whether individuals who have strong connections and who often discuss environmental issues with their neighbors are more likely to participate in environmental groups, recycle and care more about environmental issues.	Recycling (in the last 12 months, how often have you personally recycled card board packaging or paper?	Neighbor (with strong connections, medium green talk, high green help)	Households	1371
Wakefield et al. (2007)Wakefield et al. (2007)	Canada	Questionnaires	The paper explored the relationships among environmental health, social capital and collective action in the industrial city of Hamilton, Ontario, Canada.	Environmental collective actions ("attending a public meeting about a local environmental issue, and attending a public protest about a local environmental issue")	In an environmental group (yes/no)	Household	512
Leadership							

Blok et al. (2015)Blok et al. (2015)	Netherlands	Mail survey	The authors examined how factors like leadership support and exemplary pro-environmental behavior by leaders are at stake in the case of pro-environmental behavior in the workplace.	Intention to act pro-environmentally	Leadership support ("my employer informs me about the environmental impact of my behavior at work", etc.) (6 items)	Students	411
Cotterill et al. (2009)Cotterill et al. (2009)	UK	Field experiment	The authors used the data from the experiment "Canvassing projects" that recruit and train canvassers about recycling and then use them as factors to influence recycling behavior by letting them visit, share information with and encourage all households in the streets in the intervention group.	Frequency of weekly recycling	Canvass group intervention (a block leadership approach)	Households	6,580
Fatoki (2019)Fatoki (2019)	South Africa	Field experiment	The author studied the effect of leadership behavior, institutional support and workplace spirituality on hotel employees' pro-environmental behavior.	Pro-environmental behaviors ("I turn lights off when not in use", etc.) (6 items)	Leadership behavior ("seeing the owner/manager showing pro-environmental behavior influences the way that I act", etc.) (3 items)	Employees	366
Graves et al. (2019)Graves et al. (2013)	China	Questionnaires	The author tested the linkages between transformational leadership on environmental issues.	Pro-environmental behaviors ("find ways of working that are better for the environment", etc.) (12 items)	Environmental transformational leadership ("talks enthusiastically about what we need to do to protect nature") (5 items)	Employees	510
Hopper and Nielse (1991)Hopper and Nielsen (1991)	US	Field experiment	The author investigated how the block leader for recycling has an impact on recycling behavior.	Recycling score (number of times each household recycled)	Block leader treatment (recruited leaders to travel to each household on their block to talk with their neighbors and encourage them to recycle)	Households	240
Khan et al. (2019)Khan et al. (2019)	China	Questionnaires	The author investigated the relationship between supervisors' ethical leadership and organizational environmental citizenship behavior.	Organizational environmental behavior ("I help my co-workers be environmentally-friendly at work")	Supervisors' ethical leadership	Employees	447
Kim (2014)Kim et al. (2014)	South Korea	Questionnaires	The author studied the impact of motivation in work groups and social responsibility on voluntary green workplace behavior.	Workplace green advocacy ("I work with my group members to create a more environmentally-friendly workplace", etc.) (3 items)	Leader's voluntary green workplace behaviors ("using personal cups instead of disposable cups", etc.) (6 items)	Employees	496
Robertson and Barling (2012)Robertson and Barling (2013)	Multiple countries	Online survey	The paper studied how the influence of the leader's pro-environmental workplace behavior on employees' environmental behaviors.	Workplace pro-environmental behaviors ("turn lights off when not in use", etc.) (17 5-scale items)	Leaders' environmental behaviors	Students	139
Robertson and Carleton (2018)Robertson and Carleton (2018)	US	Mail survey	The paper studied how environmentally specific transformational leadership affect employees' voluntary pro-environmental behaviors.	Voluntary pro-environmental behaviors ("at work, my co-worker recycles whenever possible") (10 items)	Environmentally specific transformational leadership ("my leader is optimistic that I can help improve my organization's environmental performance") (2 items)	Employees	162

Van Laerhoven (2010)Van Laerhoven (2010)	Multiple countries	Census data	The author studied the effective local forest governance regime using a large-N cross-national dataset.	Forest monitoring activities ("do forest user groups engage in regular monitoring?") (yes/no)	Leader ("Does the user group have a leader?")	Forest groups	240
Wang et al. (2018b)Wang et al. (2018)	China	Questionnaires	The study examined the extent of the impact of green transformational leadership on employee green behavior through follower perceptions of value congruence.	Employee green behavior ("this employee puts compostable items in the compost bin") (7-item scale)	Green transformational leadership ("my leader encourages the group members to achieve the environmental goals") (6-item scale)	Employees	220
Wesselink et al. (2017)Wesselink et al. (2017)	Netherlands	Online survey	The study examined role of organization and managers and workplace pro-environmental behaviors.	Pro-environmental behavior in the workplace	Leadership support ("seeing my direct supervisor acting pro-environmentally influences my own acting")	Employees	479
Trust in others							
Baggio et al. (2015)Baggio et al. (2015)	US	Field experiment	The author investigated how the importance of trust and the environmental variability determines the outcomes of collective action using the irrigation experiments in the lab.	Investment in irrigation (generating the common water resource)	Trust is measured by amount of money sent to another participant	Students	1075
Bauwens and Eyre (2017)Bauwens and Eyre (2017)	Belgium	Online survey	The influence of interpersonal trust, which is when individuals trust others in general, to participate in a renewable energy cooperatives.	Participation in renewable energy cooperative	Interpersonal trust which captures extent to which people trust others in general	Households	2,357
Beitl (2014)Beitl (2014b)	Ecuador	Questionnaires	Authors investigated how resource characteristics and institutions influence people's behavior toward common pool resources in coastal Ecuador.	Mean shell length in each fisher's catch (in mm)	Trust that other users comply with rules-in-use	Fishers	95
Carattini et al. (2015)Carattini et al. (2015)	Multiple countries	Census data	The author studied how the share of population that trusts others affects energy consumption in 27 European countries from 1990-2007.	Energy consumption per capita (10^3 tons of oil equivalent)	Trust ("people you know personally", etc.) (in share of positive answers)	Countries	197
Cho and Kang (2016)Cho and Kang (2017)	South Korea	Tel. interview	The author studied the impact of social trust, which is when individuals trust other members in the community, on private environmental actions (donating money or volunteering to participate in an environmental group).	Private environmental behavior ("prefer to buy environmentally friendly products", etc.) (three 4-level items)	Social trust ("I believe my neighbors would help me when I ask them for help", etc.) (three 4-level items)	Households	1,348
Fairbrother (2016)Fairbrother (2016)	Multiple countries	Face-to-face	The paper studied the effect of social trust, which is the belief that one will not be cheated by a typical stranger, on environmental concern (perceptions of the prevalence and seriousness of environmental problems).	Environmental concern (perceptions of the prevalence and seriousness of environmental problems)	Social trust ("one will not be cheated by a typical stranger") (2 items)	Households	45,199
Hao et al. (2019)Hao et al. (2019)	China	Face-face interview	The study examined the ways in which social capital (measured through social networks and trust) influences people's environmental concern in China.	Pro-environmental behavior (six 4-level items)	Trust ("most people can be trusted")	Households	3,672

Macias and Williams (2014)Macias and Williams (2016)	US	Census data	The author investigated the relationship of social capital and pro-environmental behaviors.	Reduce household energy consumption (4-level item)	Most people can be trusted (5-level item)	Households	1,417
Mekonnen and Bluffstone (2017)Mekonnen et al. (2017)	Ethiopia	Face-to-face interview	The author investigated the effects of community forest on households' incentives to invest in trees located on their own farms.	Number of private tree on own land	Trust others in the village	Farmers	1,080
Meyer and Liebe (2010)Meyer and Liebe (2010)	Switzerland	Census data	The paper took into account various competing economic, psychological and sociological determinants of individuals' willingness to pay (WTP) for both public environmental and quasi-private environmental goods. The standard error is calculated using the reported t-value.	Willingness to pay in environmental protection (yes/no)	'Generalized trust ("an additive index of three 5-point questions on perceived trustworthiness, opportunism, and helpfulness")	Households	1,522
Miller and Buys (2008)Miller and Buys (2008a)	Australia	Face-face interview	The author studied how individuals who have a high level of trust and safety with their neighbors have a greater intention to perform environmentally-friendly activities.	Car washing on lawn (yes/no)	Trust and safety (5 items)	Households	209
Miller and Buys (2008b)Miller and Buys (2008b)	Australia	Questionnaires	The authors investigated how eight distinct elements of social capital predict a "feeling of responsibility" for local environmental issues in a drought-prone community.	Responsibility for water conservation and environmental conservation	Feeling of trust and safety (Do you agree that most people can be trusted?)	Households	276
Nyangena (2008)Nyangena (2008)	Kenya	Questionnaires	The authors searched for the factors that determine successful development in soil conservation such as social capital, human capital and market integration, and found that social capital measures are significant determinants of investment in soil conservation.	Soil and water conservation investment (yes/no)	Trust index (proxy by three variables reflecting solidarity in reduction of adverse shock, lending of money, food and reciprocity)	Households	556
Polman and Siangen (2008)Polman and Slangen (2008)	Multiple countries	Face-face interview	The paper studied how a high level of trust with other farmers has an impact on the restriction of intensive practices used in farming	Restriction of intensive practices (yes/no)	Social trust ("generally speaking, most people can be trusted") (yes/no)	Farmers	990
Rompf et al. (2017)Rompf et al. (2017)	Multiple countries	Online survey	The authors studied the institutional and social trust on self-reported recycling behaviors.	Recycling behaviors (three 5-scale items)	Social trust ("generally speaking, would you say that most people can be trusted, or that you can't be too careful in dealing with people?", etc.) (three 10-scale items)	Households	2,935
Sonderskov (2008)Sønderskov (2008)	Multiple countries	Questionnaires	The author studied the influence of generalized social trust (most people can be trusted) on participating in environmental organizations.	Environmental group membership (yes/no)	Generalized trust ("generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?") (yes/no)	Countries	52

Sonderskov (2009)Sønderskov (2009)	Multiple countries	Census data	The author studied the influence of generalized social trust (most people can be trusted) on recycling and consuming green products.	Recycling (recycled share of municipal waste)	Generalized trust ("generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?") (yes/no)	Countries	20
Sonderskov (2009)Sønderskov (2009)	Multiple countries	Census data	The author studied how the influence of generalized social trust (most people can be trusted) on recycling and consuming green products.	Organic food (average annual per capita consumer expenditure on organic foods)	Generalized trust ("generally speaking, would you say that most people can be trusted or that you need to be very careful in dealing with people?") (yes/no)	Countries	20
Testa et al. (2016)Testa et al. (2016)	Italy	Mail survey	The paper explored the influence of personal capabilities and moral norms, along with trust in information on energy saving actions provided by different entities on two energy saving behaviors.	Energy-saving behaviors (4 items)	Level of trust in family and friends	Students	198
Wang et al. (2018)Wang et al. (2018)	China	Face-face interview	The paper aimed to explore the factors that influence Chinese farmers' willingness to pay for health risk reductions of pesticide use by applying the contingent valuation method.	WTP to reduce pesticide use (yes/no)	Social trust (farmers' trust towards people in villages in general)	Farmers	261
Willy and Muller (2013)Willy and Holm-Müller (2013)	Kenya	Face-face interview	The author studied the effects of social influence and participation in collective action initiatives on soil conservation efforts among smallholder farmers in Lake Naivasha basin, Kenya.	Number of soil conservation practices implemented	Level of trustworthiness (trust in other individuals in the community)	Households	307
Trust in institutions							
Arpad (2018)Arpad (2018)	Multiple countries	Questionnaires	The author studied how public support could impact the sustainable development and environmentally-friendly policies in five countries (USA, UK, Italy, Sweden and Romania).	"People's willingness to support a state's increased spending on environmentally-friendly policies"	Belief in government competence	Students	13,995
Lubell et al. (2006)Lubell and Vedlitz (2006)	US	Tel. interview	The paper studied how the perceived risk, trust in policy elites, knowledge of the policy problem, and efficacy can help improve the intention to reduce air pollution.	Behavioral intentions (respondent's willingness to perform specific behaviors to reduce air pollution) (five 11-level items)	Government trust (averages the trust items for the federal government, Texas Department of Transportation, Texas Commission on Environmental Quality, U.S. Environmental Protection Agency, and local elected officials)	Households	1,326
Macias and Williams (2014)Macias and Williams (2016)	US	Census data	The authors investigated the relationship of social capital and pro-environmental behaviors.	Reduce household energy consumption (4-level item)	Trust people in the government (5-level item)	Households	1,417

Michaels and Parag (2016)Michaels and Parag (2016)	Israel	Online Survey	The paper investigated perceptions of demand reduction, load shifting and energy storage technologies as pro-consumer activities in remote controlled household appliances via smart controls to information communicated by the grid.	The acceptance of remote controlled appliances to reduce electricity use	Degree of trust in 5 Israel institutions (from 1-5)	Households	509
Polman and Siangen (2008)Polman and Slangen (2008)	Multiple countries	Face-face interview	The paper studied how a high level of trust in the government has an impact on the restriction of intensive practices used in farming	Restriction of intensive practices (yes/no)	Institutional trust (trust in agricultural administration, environmental administration, or EU)	Farmers	990
Rompf et al. (2017)Rompf et al. (2017)	Multiple countries	Online survey	The authors studied the institutional and social trust on self-reported recycling behaviors.	Recycling behaviors (three 5-scale items)	Institutional trust (trust the legal system, parliament, police, civil service, and government) (five 10-scale items)	Households	2,935
Sonderskov (2009)Sønderskov (2009)	Multiple countries	Census data	The author studied the influence of generalized social trust (most people can be trusted) on recycling and consuming green products.	Recycling (recycled share of municipal waste)	Institutional trust (trust the legal system, parliament, police, civil service, and government) (five 10-scale items)	Countries	20
Sonderskov (2009)Sønderskov (2009)	Multiple countries	Census data	The author studied the influence of generalized social trust (most people can be trusted) on recycling and consuming green products.	Organic food (average annual per capita consumer expenditure on organic foods)	Institutional trust (trust the legal system, parliament, police, civil service, and government) (five 10-scale items)	Countries	20
Testa et al. (2016)Testa et al. (2016)	Italy	Mail survey	The paper explored the influence of personal capabilities and moral norms, along with trust in information, on energy-saving actions provided by different entities on two energy saving behaviors.	Energy-saving behaviors (4 items)	Level of trust in public institutions	Students	198
Wakefield et al. (2007)Wakefield et al. (2007)	Canada	Questionnaires	The paper explored the relationships among environmental health, social capital and collective action in the industrial city of Hamilton, Ontario, Canada.	Environmental collective actions ("attending a public meeting about a local environmental issue, and attending a public protest about a local environmental issue")	Trust the government to do right	Household	512
Wang et al. (2018)Wang et al. (2018)	China	Face-face interview	The paper aimed to explore the factors that influence Chinese farmers' willingness to pay for health risk reductions of pesticide use by applying the contingent valuation method.	WTP to reduce pesticide use (yes/no)	Institutional trust (trust in local governments)	Farmers	261
Xiao and McCright (2015)Xiao and McCright (2015)	US	Census data	The authors studied the effect of institutional trust, which is when individuals have confidence in the government, on the individuals' concerns about environmental problems.	Concern about specific environmental problems (5 items)	Trust in government (trust in the executive branch of the federal government and Congress)	Households	1,620

Zannakis et al. (2015)Zannakis et al. (2015)	Sweden	Mail survey	The author investigated the impact of trust in the government, public authorities and politician on the acceptance of government regulations pertaining to on-site sewage systems and treating sewage from one or a few households not connected to the municipal wastewater grid.	Acceptance of government regulation of on-site sewage systems (OSSs) ("I will change OSS if the municipality recommends it", etc.) (3 items)	Trust in institutions in general (10-scale item)	Households	1,481
Zhou and Dai (2019)Zhou and Dai (2019)	China	Questionnaires	The paper explored haze tolerance in Beijing, Shanghai, and Guangzhou, as well as the key influential factors concerning haze tolerance from four different aspects: political trust, perceived risk, cost perception and haze knowledge.	Public's tolerance for haze pollution	Political trust (political system, political institutions, and their operation)	Households	517

Chapter 2

Social comparison in networks: A common pool resource game[1]

2.1 Introduction

For centuries, our massive exploitation of common pool resources (e.g., forests, oceans, fishing pounds and atmosphere, etc.) has caused serious damages to the environment, such as ecological disturbances and pollution (Ostrom, 2008). In his theory of the tragedy of commons, Hardins explained the massive exploitation by indicating that common pool resources (henceforth CPRs) share a same "non-excludability" property with public goods (henceforth PGs), but consumption of CPRs creates negative externality for all other people who shares the CPRs, which is known as the "subtractability" (Hardin, 1968). The "subtractability" property means that an additional CPR consumption would decrease the available resources for others. As a result, it makes the management of a CPR becoming much more complex compared to a PG because it is hard to prevent people to subtract units from a common pool.

Several existing literature supported the theory of Hardins (i.e., the theory of the tragedy of commons) by showing that when human behavior is assumed to be self-interest, open-access natural resources would undoubtedly lead to over-exploitation problem (Bromley and Cernea, 1989; Pearce and Turner, 1990). This is because individuals would maximize their resource extraction by equalizing their marginal personal gains with the marginal cost of extraction. And since a common resource is scarce, each unit of resource extracted in a common pool would causes a negative externality for others. This would give rise to an inefficiently high level of extraction, which threatens the long-term sustainability of the common (Sethi and Somanathan, 1996). The Chilean abalone war, in which the competition between poachers and fisherman in Chile to harvest abalone (the world's most

[1] This chapter is based on Tiet T. (2020), Social comparison in networks: A common pool resource game. *Submitted*.

valuable shellfish) leads to an armed conflict, is an example for the problem of the tragedy of commons (Gelcich et al., 2010).

However, several studies have challenged the work of Hardin by supporting that there is a possibility of managing the commons (Ostrom, 1990; Ostrom et al., 1994). In her study, Ostrom argued that with property rights and government regulations, one could achieve the successful management of CPRs (Ostrom et al., 1994).[2] In addition to the property rights and regulations, several existing literature suggested that social influences (e.g., norms, other-regarding preferences, social competition, etc.) are also effective ways to motivate the common resource conservation. One study indicated that individuals who have strong social preference would concern more about others' well-being, are willing to help others and desires to uphold ethical norms (i.e., other regarding preferences) (Frey and Meier, 2004).[3] For instance, in her book, Ostrom also cataloged several examples in which communities have successfully managed the CPRs without any help of the central government, from 16th century Alpine shepherds managing grazing lands to the year of 1980s Japanese villages managing communal forests (Ostrom, 1990). Additionally, some studies showed that people are willing to contribute to a public good if they know that others also contribute (i.e., conditional cooperation) Arrow (1970); Frey and Meier (2004). In this sense, ones may be motivated to extract less the CPRs if they observe the conservation efforts of others. The others could stand for other people in the community or our close friends (or neighbors) (i.e., the ones who we connect to).

In recent years, several studies have shown that networks could also play an important role in mitigating the over-extraction problem. One study indicated that when the populations dependent highly on the common resources, cooperation could also emerge and sustain if individuals are located in a network with close proximity and strong social ties (Cárdenas et al., 2015). This is because individuals often take the decisions of others that they observed into considerations before making their decisions, especially the decisions of their close friends and neighbors (Burkart et al., 2007). For instance, some behavioral economic experiments suggested that informational sharing through networks could help to restrain the resource extraction (Mantilla, 2015; Barnes-Mauthe et al., 2013). Particularly, in their study, the authors found that fisheries in a network could share information with each other and thus it helps to cooperatively reduce fish by-catch rate (Barnes-Mauthe et al., 2013). Another study showed that cooperation exists in the CPR game and network structure plays a key role in reducing the aggregate extraction level of the CPR (Mantilla, 2015).

[2] Elinor Ostrom has gotten the Nobel prize for her work in 2009.

[3] Pro-social behavior has been studied widely in the context of public good game (Isaac and Walker, 1988) and common pool resource game (Rustagi et al., 2010; Walker et al., 1990) using the experimental data.

In this paper, we investigate how the social comparison in networks (i.e., ones are influenced by their close friends or neighbors' behaviors) affect individual behaviors in the context of the CPRs. In particular, we consider that individuals are located in a network and there is an assimilation in social comparison which ones imitate the behaviors of others in their networks (Mussweiler et al., 2004). It should be noted that in the presence of network, agents care more about their neighbors' behaviors since they are linked to each other rather than the strangers who are not in their network. Our objective is to explore how network structures and social comparison can lead to sustainable use and improve the management of the CPRs. More specifically, we aim to investigate how the assimilation in social comparison in different networks could impact individual behaviors in the common resource game.

In order to answer this question, we consider in our model that individuals care about the behaviors of the agents that they connect to (i.e., friends or neighbors). In other words, each agent is located in a given network and they compare their actions to their direct neighbors (i.e., social comparison in network). We assume that the social comparison is assimilative which means that ones change their behaviors in order to minimize the difference/distance between them and others, which is also known as the "conformity". We consider the exogenous network in order to observe the causal effect of network on individual behavior as network varies. We use the static framework of Nash equilibrium to examine the outcome of the CPR game under assumptions: each agent in a network has to decide how much effort to put in extracting the common resource and as the same time take his or her direct neighborhood behaviors into account in order to maximize his or her personal utility. Our results suggest that assimilation in social comparison can shape individual behavior in the way that promotes the resource conservation. But, the assimilation effect on conservation behavior depends conditionally on network structure. More specifically, assimilation in comparison performs sufficiently well in centralized networks (like a star network) than decentralized networks (like a circle or complete network) in encouraging the resource conservation.

The paper proceeds as follows. Section 2 studies the common resource game with social comparison with the general model. In Section 3, we compute the Nash equilibrium with the assumptions about the functional form of the production function and social comparison. In Section 4, we discuss the welfare analysis. Section 5 summarizes the results of our numerical analysis. The conclusion and discussion are discussed in Section 6.

2.2 Common pool resource game

2.2.1 Setup

Let consider that there are N agents, a typical agent is denoted by i. Each agent i has a set of neighbors which is denoted $N_i(g)$ (i.e., a network of i). Let $\mathbf{G}$ is an $N \times N$ adjacency matrix, its element g_{ij} represents the relationship between i and j. In particular, if i is linked to j, then we have $g_{ij} = 1$ for $j \in N_i(g)$ and if i is not linked to j, then we have $g_{ij} = 0$ for $j \notin N_i(g)$. We suppose that the network is *undirected* which requires that if $g_{ij} = 1$ then $g_{ji} = 1$, which means that if i is neighbor of j, then j is also neighbor of i.[4] The network of i is a set of nodes that is linked to i: $N_i(g) = \{j \setminus i : g_{ij} = 1\}$ or $N_i(g) = \{j | ij \in g\}$. Let $k_i = |N_i(g)|$ be agent i's number of neighbors or agent i's centrality.[5]

An agent i will face a decision problem of how to optimally allocate his/her effort x_i to extract the resources when taking their neighbors' behaviors into account. We assume that agent i's effort is bounded $x_i \in [0, \bar{x}]$, where $\bar{x}$ is the effort capacity. We assume that total effort function $f(X)$ is concave, in which $f(0) = 0$, $f(X) > 0$ if $X > 0$, $f^{'}(X) > 0$ and $f^{''}(X) \leq 0$, where the total effort $X = \sum_i x_i = x_i + x_{-i}$. According to "substractability" property of the CRP, the share of common resources extracted by i is $\frac{x_i}{x_i + x_{-i}}$, which is the proportion of effort that i make in extracting the resources with respect to the total sum of all agents' efforts. Therefore, we have an agent i's effort function could be written as: $f(X)\frac{x_i}{x_i + x_{-i}}$. This means that agent i would suffer a resource share loss (i.e., benefit loss from the CPR) as other agents increase their extraction effort x_{-i} (i.e., "substractability" property).

Each agent has a network of neighbors in which he or she could observe others' behaviors and compare his or her behavior with others. We denote the difference between agent i and his/her neighbors by $I(x_i, \mathbf{x}_{N_i(g)}; \delta_i)$, where $\mathbf{x}_{N_i(g)}$ is a set of i's neighborhood efforts, and δ_i is the comparison parameter which is heterogeneous across agents and takes negative values (i.e., $\delta_i < 0$). Suppose that if $I(x_i, \bar{x}_{N_i(g)}; \delta_i) = \delta_i(x_i - \bar{x}_{N_i(g)})^2$ where $\bar{x}_{N_i(g)}$ is the neighborhood average extraction effort, the negative $\delta_i < 0$ will then refer to the assimilation in comparison (i.e., conformity) which means that agents change their behaviors in order to fit in their groups. We do not explore the possibility of the contrast in comparison (i.e., $\delta_i > 0$) in this study because no agent is willing to differentiate with others by

[4]For instance, suppose that there are 3 agents in the network, $N = \{1, 2, 3\}$ and the adjacency matrix $\mathbf{G}$ is given by

$$\mathbf{G} = \begin{bmatrix} 0 & 1 & 1 \\ 1 & 0 & 1 \\ 1 & 1 & 0 \end{bmatrix}$$

This matrix suggests that there is a circle network of 3 agents in which agent 1 links to agent 2 and 3, agent 2 links to 1 and 3, and 3 links to 1 and 2.

[5]Centrality of a node is the number of agents that are connected to the agent i (Schweitzer et al., 2009).

putting less effort in extracting the common resource (since there is a "substractability" property of the common). On the other hand, because of the contrast in comparison, all agents would definitely put as much as effort to extract the resource and thus this would lead to the over-exploitation of the CPRs.

We consider that there exits an ability parameter $\eta_i > 0$ such that agent i gains an amount $\eta_i x_i$ for each unit of x_i increasing. In other words, agents are heterogeneous in their ability (i.e., $\eta_i \neq \eta_j$) and an agent who has higher ability (higher value of η) would be able to gain a higher benefit from each unit of extracted resource. There exist two types of heterogeneity in our model: *idiosyncratic heterogeneity* and *peer heterogeneity*. The *idiosyncratic heterogeneity* captures the fact that agents differ in their ability in extracting the common resource (Patacchini and Zenou, 2009). The *peer heterogeneity* is come from the different network structure, different comparison parameter and thus agents have different reference group in the social comparison. For example, with a network of N agents, the central agent of the star network has a same number of direct neighbors compared to the agent of complete network. But, these two agents have different reference groups because each neighbor of the agent in the complete network has $N-1$ neighbors, while each neighbor of the agent in the center of the star network has only one neighbor. The peer heterogeneity is also come from the different in comparison parameter which means that agent care differently about their neighbors' actions.

2.2.2 Model

In the spirit of Sethi and Somanathan (1996), we extend the model of CPR game by taking the role of network and social comparison into account.[6] For a given network structure, agent i's utility function is written as follows:

$$U_i(x_i) = \underbrace{f(X)\frac{x_i}{X}}_{benefit} - \underbrace{\gamma x_i^2}_{\text{cost}} + \underbrace{\eta_i x_i}_{\text{ability}} + \underbrace{I(x_i, \mathbf{x}_{N_i(g)}; \delta_i)}_{\text{social comparison}} \tag{2.1}$$

$$\text{s.t} \qquad x_i \leq \bar{x}, \quad x_i \geq 0$$

where, $X = x_i + x_{-i}$ is the total effort and $\bar{x}$ is the effort's capacity.
From the optimization problem 2.1, we have the following Lagrangian.

$$\mathcal{L}(x_i) = f(X)\frac{x_i}{X} - \gamma x_i^2 + \eta_i x_i + I(x_i, \mathbf{x}_{N_i(g)}; \delta_i) - \mu_1(x_i - \bar{x}) + \mu_2 x_i \tag{2.2}$$

[6] We also follow the paper of (Patacchini and Zenou, 2009), which studied the social comparison in crime, for the idea of how to model the social comparison in the network.

The Karush-Kuhn-Tucker conditions

In the spirit of the Karush-Kuhn-Tucker (KKT) theorem, we have

$$\frac{\partial \mathcal{L}(x_i)}{\partial x_i} = 0 \tag{2.3}$$

$$\mu_1(x_i - \bar{x}) = 0 \tag{2.4}$$

$$\mu_2 x_i = 0 \tag{2.5}$$

$$\mu_m \geq 0, \;\; m = \{1,2\} \tag{2.6}$$

$$x_i \leq \bar{x} \tag{2.7}$$

$$x_i \geq 0 \tag{2.8}$$

Concerning the complementary slackness condition 2.5 which is $\mu_2 x_i = 0$, we consider following cases.

Case 1. The condition $x_i \geq 0$ is binding. In this case, we have $x_i = 0$. Then, the agent i's utility equals to

$$U_i(0) = I(0, \mathbf{x}_{N_i(g)}; \delta_i)$$

We observe that $U_i(0) \leq 0$ since there is an assimilation in comparison (i.e., $\delta_i < 0$). At the equilibrium, $\underline{x}^c = 0$ for all i and thus $U_i(0) = I(0, \mathbf{x}_{N_i(g)}; \delta_i) = 0, \forall \delta_i < 0$.

Case 2. The condition $x_i \geq 0$ is not binding. In this case, in order for the slackness condition 2.5 to be satisfied, we need $\mu_2 = 0$. Now, concerning the complementary slackness conditions 2.4 which is $\mu_1(x_i - \bar{x}) = 0$, by the same logic, we also consider the two following cases:

Case 2.a. Constraint $x_i \leq \bar{x}$ is binding which is $x_i = \bar{x}$. In this case, we have a corner solution $\bar{x}^c = \bar{x}$.

Case 2.b. Constraint $x_i \leq \bar{x}$ is not binding. Thus, we need $\mu_1 = 0$ in order for the complementary slackness conditions 2.4 to be satisfied. This is a case that agent's effort cannot be equal to zero or reach the maximum effort's capacity, i.e., $x_i \in (0, \bar{x})$. Then, we can write the KKT conditions as follows:

$$\frac{\partial \mathcal{L}(x_i)}{\partial x_i} = f^{'}(X)\frac{x_i}{X} + f(X)\frac{x_{-i}}{X^2} - 2\gamma x_i + \eta_i + \frac{\partial I_i(x_i)}{\partial x_i} = 0, \tag{2.9}$$

where, $I_i(x_i) \equiv I(x_i, \mathbf{x}_{N_i(g)}; \delta_i)$. Thus, this KKT condition is necessary condition for the maximization problem.

Sufficient condition of optimality

In order to ensure the existence of a maximum, we need $\frac{\partial^2 U_i}{\partial x_i^2} \leq 0$. Following the second order sufficient condition, we have the following inequality[7]

$$\frac{\partial U_i^2}{\partial^2 x_i} = \frac{1}{X^2}\left\{f^{''}(X)Xx_i + 2x_{-i}\left(f^{'}(X) - \frac{f(X)}{X}\right)\right\} - 2\gamma + \frac{\partial^2 I_i(x_i)}{\partial x_i^2}$$

Since $x_i, x_{-i} > 0$, we have $f^{''}(X) < 0$ and $f^{'}(X)X - f(X) < 0$[8]. The condition $\frac{\partial^2 U_i}{\partial x_i^2} \leq 0$ if we have $\frac{\partial^2 I_i(x_i)}{\partial x_i^2} \leq 0$. Thus, the condition $\frac{\partial^2 U_i}{\partial x_i^2} \leq 0$ will hold in the case of assimilation in comparison if $\frac{\partial^2 I_i(x_i)}{\partial x_i^2} \leq 0$ holds.

Therefore, the sufficient condition leads us to the following Lemma 1.

Lemma 1. The optimization problem always has a maxima in the case of assimilation in comparison (i.e., $\delta_i < 0$) if $\frac{\partial^2 I_i(x_i)}{\partial x_i^2} \leq 0$.

In the case of assimilation in comparison, agents mitigate others' behaviors in their network. This leads to the fact that $\frac{\partial I_i(x_i)}{\partial x_i} < 0$ for $x_i \neq \mathbf{x}_{N_i(g)}$ (i.e., x_i is different from the standard neighborhood extraction). Thus, in order to ensure a maxima, we need $\frac{\partial^2 I_i(x_i)}{\partial x_i^2} \leq 0$ which means that a more difference in extraction compared to the standard neighborhood extraction, a more agents suffer from the benefit loss form the social comparison. Therefore, we need the above condition holds in order for the optimization problem to have a maxima i.e., an interior equilibrium solution). If not, the all agents would choose to extract the resource with the maximum effort's capacity. Thus, it indeed leads to an over-exploitation problem of a CPR.

2.3 Nash equilibrium level of effort

In order to calculate explicit solution for the equilibrium level of effort and welfare analysis in next Section, we make some assumptions about the functional forms of the total effort function and social comparison.

In the spirit of Walker et al. (1990) in limit-access common pool resource, we let $f(X) = aX - bX^2$ be the effort function for the total effort X, where $a \geq 0$ and $b \geq 0$. We can check that the function $f(X)$ satisfies our assumptions.

$$f(X) \geq 0 \text{ if } X \leq \frac{a}{b}, \qquad f^{'}(X) = a - 2bX \geq 0 \text{ if } X \leq \frac{a}{2b}, \qquad f^{''}(X) = -2b \leq 0.$$

[7] See the proof in Appendix.
[8] $f(x)$ is a concave function

Let $\bar{x}_{N_i(g)}$ be the reference level of effort that the agent i compared to. We consider the social comparison as a difference between $\bar{x}_{N_i(g)}$ and x_i, such that

$$I(x_i, \bar{x}_{N_i(g)}; \delta_i) = \delta_i (x_i - \bar{x}_{N_i(g)})^2.$$

It should be noted that the reference level could be the neighbor's average, maximum or minimum level of effort. We suppose that the reference level is the direct neighbors' average level of effort. Thus, we have

$$\bar{x}_{N_i(g)} = \frac{1}{k_i} \sum_{j}^{N} g_{ij} x_j,$$

where, k_i is number of agent i's direct neighbors.

Note that in the case that we have $\delta_i < 0$, there exists an assimilation in comparison, which means that agents would suffer a negative impact of the social comparison for each unit of effort higher than the reference level. When $\delta_i > 0$, we have the contrast in comparison. In this case, each agent would maximize his or her utility by maximizing the distance between him or her and other agents (i.e., by extracting more or less than other agents). For instance, in the presence of assimilation in comparison (i.e., $\delta_i < 0$), we could simply check that

$$\frac{\partial I_i(x_i)}{\partial x_i} = 2\delta_i (x_i - \bar{x}_{N_i(g)}) \leq 0 \ \text{ if } \ x_i - \bar{x}_{N_i(g)} \geq 0.$$

And we have also that

$$I_{xx} = \frac{\partial^2 I_i(x_i)}{\partial x_i^2} = 2\delta_i < 0.$$

This suggests that a more increasing extraction of common resource, a more the agent suffer negative impact from the comparison. Thus, from the Lemma 1, we could confirm that the sufficient condition for optimality always holds in the case of assimilation in comparison.

In this study, we will focus on different scenarios (i.e., how the different value of δ_i and network structure) can help impacts on agents' behaviors in extracting/consuming the common pool resource.

2.3.1 Equilibrium

We now examine the outcome of the model with social comparison under the assumption that agents are heterogeneous in the social comparison (i.e., agents care differently about their direct neighbors' actions).

Let $\mathbf{x} = (x_1, x_2, x_3, ..., x_N)$ and thus $\mathbf{x}$ is the solution of the following maximization problem

$$\max_{x_i} U_i(\mathbf{x}) = \max_{x_i} \left\{ f(X)\frac{x_i}{X} - \gamma x_i^2 + \eta_i x_i + \delta_i \left(x_i - \frac{1}{k_i}\sum_j^N g_{ij}x_j \right)^2 \right\} \tag{2.10}$$

s.t $\quad x_i \leq \bar{x}, \quad x_i \geq 0$

From the optimization problem 2.10, we have the following Lagrangian

$$\mathcal{L}(\mathbf{x}) = (a - bX)x_i - \gamma x_i^2 + \eta_i x_i + \delta_i \left(x_i - \frac{1}{k_i}\sum_j^N g_{ij}x_j \right)^2 - \mu_1(x_i - \bar{x}) + \mu_2 x_i \tag{2.11}$$

We have the F.O.C of the Lagrangian as follows.

$$\frac{\partial \mathcal{L}(\mathbf{x})}{\partial x_i} = a - b(X + x_i) - 2\gamma x_i + \eta_i + 2\delta_i \left(x_i - \frac{1}{k_i}\sum_j^N g_{ij}x_j \right) - \mu_1 + \mu_2 = 0$$

Recall the KKT conditions, we can check whether all the conditions are satisfied.
Case 1. We have the corner solution $\underline{x}^c = 0$ and the utility $U_i(0) = 0$. In this case, agent make no effort in extracting the resource and thus there will be no benefit gained at this lower corner solution.

Case 2. We have $x_i > 0, \forall i$. Thus, by the complementary slackness condition 2.5 and 2.4, we have 2 following cases.

Case 2.a. We have the constraint $x_i \leq \bar{x}$ is binding. Then, by the slackness condition, we have $x_i = \bar{x}$ and $\mu_1 > 0$. Thus, we have

$$\frac{\partial \mathcal{L}(\mathbf{x})}{\partial x_i} = a - b(X + x_i) - 2\gamma x_i + \eta_i + 2\delta_i \left(x_i - \frac{1}{k_i}\sum_j^N g_{ij}x_j \right) - \mu_1 = 0$$

From the slackness condition, we have $x_i = \bar{x}$. Thus, at the equilibrium, we have $\bar{x}^c = \bar{x}$ in which all agents extract the resource at the maximum effort's capacity. We have a upper corner solutions, such that

$$\bar{x}^c = \bar{x}, \quad \text{and} \quad \mu_{1,i} = a + \eta_i - [b(N+1) + 2\gamma]\bar{x}.$$

It should be noted that this upper corner solution will exist if and only if we have the condition $\mu_{1,i} = a + \eta_i - [b(N+1) + 2\gamma]\bar{x} \geq 0$ to be satisfied.

Case 2.b. In this case, we have $\mu_1 = 0$. Let x^* be the interior equilibrium solution. From the KKT condition, we have

$$x_i = \frac{1}{2(b+\gamma-\delta_i)}(a+\eta_i - b\sum_{j\neq i}^{N} x_j - 2\delta_i \frac{1}{k_i}\sum_{j}^{N} g_{ij}x_j) \tag{2.12}$$

Symmetric case

Before going the general case in which the agents are heterogeneous in their social comparison, we first discuss the situation that all agents are identical. In this case, we have $\eta_i = \eta$ which means that all agents are identical and thus has a same ex-ante heterogeneity. From Equation (2.12), we have the first proposition as follows:

Proposition 1. When $\eta_i = \eta$, we have $x^* = x_i^* = x_j^*$ at the equilibrium

$$x^* = \frac{a+\eta}{(N+1)b+2\gamma} \tag{2.13}$$

When agents are identical, a higher ability agent (i.e., agent has a higher value of η) will put more effort in extracting the common resource. On the other hand, increasing extraction cost by either increasing the value of γ could incentivize agents to reduce their extraction efforts. Another way to reduce extraction effort is by reducing the parameter a or/and increasing the parameter b.[9] Therefore, in order to incentivize the common resource conservation, we should increase the cost of resource extraction and reduce individual heterogeneity as well as reduce the profitability of the effort function (Poteete and Ostrom, 2004).

It should be noted that when agents are homogeneous in their ability, we observe the social comparison and network structure do not have any influence on agent's behavior. This is because that all agents are identical and thus they would have a same equilibrium solution. Therefore, at the equilibrium, social comparison does not play any role because agents do not have to care about the difference them and their direct neighbors.

General case

In this case, we have $\eta_i \neq \eta_j \neq \eta, \forall i \neq j$ which suggests that agents are heterogeneous in their ability in extracting the resource. Since agents are not identical because of the idiosyncratic heterogeneity and also because of peer heterogeneity (they are also different

[9]Recall that a is a parameter of the effort function $f(X) = aX - bX^2$. A lower value of a and higher value of b, a less benefit gains from extracting the common resource.

because of the different network structure and thus have the different reference group in the social comparison), each agent would have different equilibrium effort at the equilibrium.

Let $\mathbf{x}^*$ is a $N \times 1$ column matrix (vector) of each agent equilibrium extraction effort $x_1^*, x_2^*, x_3^*, ..., x_N^*$. We could simply rewrite Equation (2.12) as follow.

$$\mathbf{x}^* = \frac{1}{2(b+\gamma)}(\boldsymbol{\iota} + \alpha \boldsymbol{\Phi}_1 \mathbf{x}^*)$$

where, $\alpha = \frac{1}{2(b+\gamma)}$, the $N \times N$ matrix $\boldsymbol{\Phi}_1$ is

$$\boldsymbol{\Phi}_1 = 2\boldsymbol{\delta}(\mathbf{I} - \mathbf{KG}) - b\boldsymbol{\Delta}$$

in which, $\boldsymbol{\iota}$ is a $N \times 1$ column matrix which each element equals to $a + \eta_i$, matrix $\boldsymbol{\delta}$ is a $N \times N$ matrix of the comparison parameter such that

$$\boldsymbol{\delta} = \begin{bmatrix} \delta_1 & 0 & ... & 0 \\ 0 & \delta_2 & ... & 0 \\ ... & ... & ... & ... \\ 0 & 0 & ... & \delta_N \end{bmatrix},$$

$\mathbf{K}$ is a $N \times N$ matrix of the number of network connections such that

$$\mathbf{K} = \begin{bmatrix} \frac{1}{k_1} & 0 & ... & 0 \\ 0 & \frac{1}{k_2} & ... & 0 \\ ... & ... & ... & ... \\ 0 & 0 & ... & \frac{1}{k_N} \end{bmatrix},$$

$\boldsymbol{\Delta}$ is a $N \times N$ matrix such that

$$\boldsymbol{\Delta} = \begin{bmatrix} 0 & 1 & ... & 1 \\ 1 & 0 & ... & 1 \\ ... & ... & ... & ... \\ 1 & 1 & ... & 0 \end{bmatrix},$$

and the $N \times N$ matrix $\mathbf{G}$ which is known as the adjacent matrix.

Proposition 2. Let $\mathbf{x}^* = (x_1^*, x_2^*, x_3^*, ..., x_N^*)$ be the equilibrium level of extraction. If the following matrix $(\mathbf{I} - \alpha\boldsymbol{\Phi}_1)$ is invertible, then the CPR game has an interior equilibrium solution which equals to

$$\mathbf{x}^* = \frac{1}{2(b+\gamma)}(\mathbf{I} - \alpha\mathbf{\Phi}_1)^{-1}\boldsymbol{\iota}, \tag{2.14}$$

where, $\mathbf{\Phi}_1 = 2\boldsymbol{\delta}(\mathbf{I} - \mathbf{KG}) - b\mathbf{\Delta}$.

From this closed form solution, one can calculate the interior equilibrium level of effort for a given network structure. We observe that the equilibrium solution depending positively on the agent's ability and negatively on extraction cost. We can also observe that a higher comparison parameter results in a lower extraction of the common resource in the case of contrast in comparison ($\delta_i < 0$). In the case of assimilation in comparison, a more increasing in the comparison parameter, a higher probability that there is an over-exploitation of the common. This interior solution also suggests that the network structure would play a key role in encouraging the conservation of the common resource in a way that a network with more connections would have lower level of extraction than the one with fewer connections.

2.3.2 Over-exploitation of the CPR

As discussed previously, we have three equilibrium solutions: $\underline{x}^c = 0$, $\bar{x}^c = \bar{x}$ and x^* which is a solution of the following matrix $\mathbf{x}^* = \frac{1}{2(b+\gamma)}(\mathbf{I} - \alpha\mathbf{\Phi}_1)^{-1}\boldsymbol{\iota}$. But, we will focus our discussion on the upper corner and the interior equilibrium solution since the lower corner solution in which all agents have zero utility is not interesting to study. By assuming that $x_i > 0, \forall i$, agents could either decide to make an effort which equals to the maximum effort capacity $\bar{x}$ or the interior equilibrium x^*. It should be important to note that $x^* < \bar{x}$ and thus from a policy-maker's point of view, we want to avoid the solution $\bar{x}^c = \bar{x}$ which leads to the over-exploitation of the common.

In fact, individual agent i would prefer x_i^* to $\bar{x}_i^c$ if and only if

$$U_i(\mathbf{x}_i^*) \geq U_i(\bar{\mathbf{x}}_i^c). \tag{2.15}$$

Since we have $\bar{x}_i - \bar{x}_{N_i(g)} = 0$, the previous condition is equivalent to

$$f(X^*)\frac{x_i^*}{X^*} - \gamma x_i^{*2} + \eta_i x_i^* + \delta_i(x_i^* - \bar{x}^*_{N_i(g)})^2 \geq f(\bar{X})\frac{\bar{x}_i^c}{\bar{X}} - \gamma(\bar{x}_i^c)^2 + \eta_i \bar{x}_i^c, \tag{2.16}$$

where, $\bar{X} = \sum_i \bar{x}_i^c$ and $X^* = \sum_i x_i^*$.

Symmetric case

In the symmetric case, we have $x_i^* = x_j^*$ and thus $x_i^* - \bar{x}_{N_i(g)}^* = 0$. Then, the inequality (2.16) is equivalent to

$$f(X^*)\frac{x^*}{X^*} - \gamma x^{*2} + \eta_i x^* \geq f(\bar{X})\frac{\bar{x}_i^c}{\bar{X}} - \gamma(\bar{x}_i^c)^2 + \eta_i \bar{x}_i^c$$

Since $x^* - \bar{x} \leq 0$, we obtain that

$$x^* \geq \frac{a+\eta}{Nb+\gamma} - \bar{x}.$$

Therefore, in the symmetric case, in order to avoid the over-exploitation problem, we need to ensure there is a sufficiently high effort capacity $\bar{x}$. However, in reality, this condition is difficult to be satisfied since agents' effort capacity are always bounded (i.e., each agents cannot to put as much efforts as possible or put infinity effort to extract as many as possible the CPR). From this condition, we could also observe that the over-exploitation would not be easily bypassed unless we have either a sufficiently high extraction cost γ or low benefit gained from CPR extraction (i.e., if there is a low parameter value of a or η). It should be noted that increasing N would help to avoid the over-exploitation problem but this would not be a good solution because too large value N (i.e., there are too many agents) would definitely lead to the situation of excess demand because of the resource scarcity.

General case

Let $\theta_i^* = x_i^* - \bar{x}_{N_i(g)}^*$ be the difference between the equilibrium of i and the average equilibrium extraction of his/her direct neighbors. In some cases (for example, symmetric network such as a complete and circle network in which agents have a same number of network connection), the θ^* equals to zero because all agents are identical. However, generally, we assume that $\theta_i^* \geq 0, \forall i$. We have the condition (2.16) equivalent to

$$\gamma x_i^* + \frac{b(X^* x_i^* - N\bar{x}^2) - \delta_i(\theta_i^*)^2}{x_i^* - \bar{x}} \geq a - \gamma\bar{x} + \eta_i$$

Therefore, this leads us to the following proposition.

Proposition 3. An agent i would prefer the interior equilibrium x_i^* which is an element of the matrix $\mathbf{x}^* = \frac{1}{2(b+\gamma)}(\mathbf{I} - \alpha\mathbf{\Phi}_1)^{-1}\boldsymbol{\iota}$ to the upper corner equilibrium $\bar{x}_i^c = \bar{x}$ if there exists sufficiently high extraction cost γ or low benefit gained from CPR extraction (i.e., if there is a low parameter value of a or η) such that $\gamma x_i^* + \frac{b(X^* x_i^* - N\bar{x}^2) - \delta_i(\theta_i^*)^2}{x_i^* - \bar{x}} \geq a - \gamma\bar{x} + \eta_i$

This proportion suggests that with γ is sufficiently large which means that the cost of extraction has to be sufficiently high, we can avoid the over-exploitation problem of the common because the agent always prefers the interior solution x^* to the corner one $\bar{x}^c = \bar{x}$. According the result of the proposition 3, it is interesting to separate our discussions into two different parts: the impact of neighborhood decisions (θ_i^*) and the impact of social comparison (δ_i).

Firstly, if $\theta_i^* = 0$, the previous condition is equivalent to

$$\gamma x_i^* + \frac{b(X^* x_i^* - N\bar{x}^2)}{x_i^* - \bar{x}} \geq a - \gamma \bar{x} + \eta_i$$

. It should be noted that in the case that θ_i^* closes to zero means that there is no big difference between the equilibrium extraction of agent i and his/her direct neighbors. This result is close to the symmetric case as discussed previously.

$$x^* \geq \frac{a + \eta}{Nb + \gamma} - \bar{x}.$$

Thus, the over-exploitation problem will be more likely to happen with $\theta_i^* = 0$.

However, if $\theta_i^* \neq 0$, a high value of θ_i^* could help to avoid the over-extraction of the common resource since there is an assimilation in comparison (i.e. $\delta_i < 0$). In order to bypass the over-exploitation problem, we $\theta_i^* = x_i^* - \bar{x}^*_{N_i(g)} > 0$ which means that agents extract more resource than their direct neighbors at the equilibrium.

Secondly, since there is an assimilation in comparison, we would also have $\theta_i^* \to 0$ as δ_i increases. This is because it is too costly for agents to differentiate with their neighbors by extracting more or less the common resource. Thus, an assimilation in comparison with low assimilation effect (i.e., low value of the parameter δ_i) could help to motivate agents to conserve the common pool resource.

Therefore, maintaining a sufficiently high extraction cost of the CPR will not be the only solution to avoid the over-exploitation problem. Encouraging the assimilation in social comparison could also help to conserve the CPRs if there exists $\theta_i^* > 0$.

2.4 Welfare analysis

Let consider that the social planner is an utilitarian so he would maximize the total agent's payoff.

$$\max_{x_i,x_2,\dots,x_N} \sum_i U_i(\mathbf{x}) = \max_{x_i,x_2,\dots,x_N} \sum_i^N \left\{ f(X)\frac{x_i}{X} - \gamma x_i^2 + \eta_i x_i + \delta_i \left(x_i - \frac{1}{k_i}\sum_j^N g_{ij}x_j \right)^2 \right\} \tag{2.17}$$
$$\text{s.t } 0 \leq x_i \leq \bar{x}.$$

By taking the F.O.C of Equation (2.17) with respect to x_i for all $i = 1, ...N$, we have

$$a - 2b\sum_i^N x_i - 2\gamma x_i + \eta_i + 2\delta_i \left(x_i - \frac{1}{k_i}\sum_j^N g_{ij}x_j \right) = 0$$

Then, we obtain

$$x_i = \frac{a + \eta_i - \frac{2\delta_i}{k_i}\sum_j g_{ij}x_j}{2(Nb + \gamma - \delta_i)}$$

In the case of symmetric agents (i.e., $\eta_i = \eta, \forall i$), we have the social optimal effort $\hat{x}$ which equals to

$$\hat{x} = \frac{a + \eta}{2(Nb + \gamma)}. \tag{2.18}$$

In general, we have heterogeneous agents in which $\delta_i \neq \delta_j \neq \delta$. Let $\hat{\mathbf{x}}$ be the $N \times 1$ matrix of the social optimal extraction effort. In the matrix formula, we have

$$\hat{\mathbf{x}} = \frac{1}{2(b + \gamma)}\boldsymbol{\iota} + 2\alpha\boldsymbol{\Phi}_2\hat{\mathbf{x}}$$

where, $\alpha = \frac{1}{2(b+\gamma)}$, the $N \times N$ matrix $\boldsymbol{\Phi}_2$ such that

$$\boldsymbol{\Phi}_2 = \boldsymbol{\delta}(\mathbf{I} - \mathbf{KG}) - b\boldsymbol{\Delta},$$

and the definition of other matrices are similar to the previous session. Thus, if the following matrix $(\mathbf{I} - 2\alpha\boldsymbol{\Phi}_2)$ is invertible, then we have the social optimal extraction effort as follows:

$$\hat{\mathbf{x}} = \frac{1}{2(b + \gamma)}(\mathbf{I} - 2\alpha\boldsymbol{\Phi}_2)^{-1}\boldsymbol{\iota}. \tag{2.19}$$

Efficiency

In the symmetric case, by comparing the interior equilibrium effort x^* (in Equation (2.13)) and the social optimal effort $\hat{\mathbf{x}}$ (in Equation (2.18)), we observe that for any $N > 1$, we always have $\hat{x} < x^*$. We can also check that the Nash equilibrium is efficient if and only if $U(x^*) = U(\hat{x})$.

$$\begin{aligned} & U(x^*) = U(\hat{x}) \\ \Leftrightarrow \quad & (a - bX^*)x^* - \gamma(x^*)^2 + \eta x^* = (a - Nb\hat{x})\hat{x} - \gamma\hat{x}^2 + \eta\hat{x}. \end{aligned}$$

Let Δ_u be the difference between $U(x^*)$ and $U(\hat{x})$. Then, we have

$$\Delta_u = (\hat{x} - x^*)(a - bN(\hat{x} + x^*) + \eta).$$

Thus, $\Delta_u = 0$ if and only if we have $x^* = \hat{x}$ or $x^* = \frac{a+\eta}{bN} - \hat{x}$.

This leads us to the following proposition.

Proposition 4. The Nash equilibrium extraction of the common resource is efficient if there exists a network size N and an equilibrium extraction x such that

$$x = \hat{x} \quad \text{or} \quad N > \frac{2\gamma}{b} \quad \text{and} \quad x = \frac{a+\eta}{bN} - \hat{x}, \tag{2.20}$$

where, $\hat{x} = \frac{a+\eta}{2(Nb+\gamma)}$.

It should be noted that if the above condition of x does not hold then the Nash equilibrium effort will be inefficient, i.e., we will have $U(\hat{x}) > U(x^*)$ for $\hat{x} < x^*$. We can observe that by substituting $\hat{x}$ into $x = \frac{a+\eta}{bN} - \hat{x}$, we obtain

$$x = \frac{(a+\eta)(Nb + 2\gamma)}{2Nb(Nb+\gamma)}. \tag{2.21}$$

However, this equilibrium effort will only be valid (i.e., $U(x) > 0$) if there exists $N > \frac{2\gamma}{b}$. For instance, when $b = 0.1$ and $\gamma = 0.8$ (see the Numerical analysis in next Section), we need $N > 16$ in order to have $U(x) > 0$. Therefore, the condition $x = \frac{a+\eta}{bN} - \hat{x}$ is difficult to achieve in our model.

Another solution for the Nash equilibrium to be efficient is to have $x^* = \hat{x}$. Thus, an interesting question is how to motivate individuals to move toward the social optimum.

In order to answer this question, let Δ_x be the difference between x^* and $\hat{x}$. Then, we have

$$\begin{aligned}\Delta_x &= \frac{a+\eta}{2(Nb+\gamma)} - \frac{a+\eta}{(N+1)b+2\gamma} \\ &= \frac{(a+\eta)(1-N)b}{2(Nb+\gamma)[(N+1)b+2\gamma]}.\end{aligned}$$

This leads us to the following proposition.

Proposition 5. The Nash equilibrium extraction is efficient if there exist parameters a, η and γ such that $\Delta_x = 0$, where

$$\Delta_x = \frac{(a+\eta)(1-N)b}{2(Nb+\gamma)[(N+1)b+2\gamma]}. \tag{2.22}$$

We observe that $\Delta_x \to 0$ as a, η decrease and γ increases. This suggests that it is important for policy maker to ensure a sufficiently high extraction cost and low agent ability in order to motivate individuals to move toward the socially optimal extraction. It should be noted that when $N = 1$, we would have $\Delta_x = 0$ which means that there is only one agent who consumes the common resource. And, a more increasing in number of agents N, a less likely to achieve the efficiency.

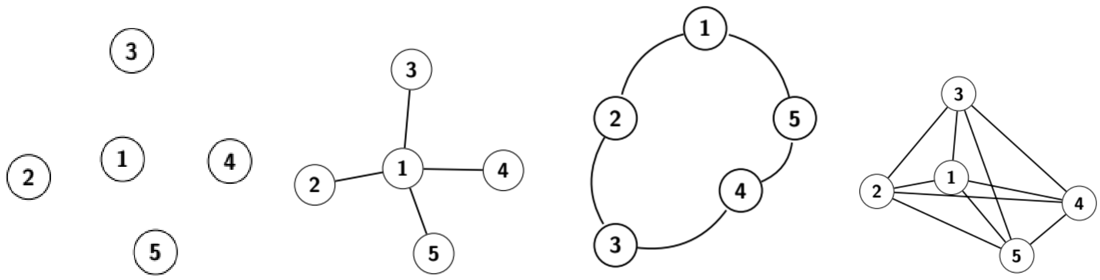
In the general case when agents are identical, the problem becomes much more complication. Let us recall the interior equilibrium solution (see Equation (2.14)) as follows:

$$\mathbf{x}^* = \frac{1}{2(b+\gamma)}(\mathbf{I} - \alpha\mathbf{\Phi}_1)^{-1}\boldsymbol{\iota},$$

where, $\mathbf{\Phi}_1 = 2\boldsymbol{\delta}(\mathbf{I} - \mathbf{KG}) - b\mathbf{\Delta}$. By comparing with the social optimal effort (see Equation (2.19)), we observe that $2\mathbf{\Phi}_2 < \mathbf{\Phi}_1$ and thus $\hat{\mathbf{x}} > \mathbf{x}^*$. This suggests that the socially optimal effort is always efficient when there is a presence of network structure. Since we know that the interior equilibrium is always inefficient, a question arises is how could we achieve the efficiency. By comparing the difference between the interior and the social optimum, we observe that the inefficiency is come from the externality from the peer effect and the network structure in the matrix $\mathbf{\Phi}$. However, since the social structure is given (i.e., it is fixed), it is interesting to check which social structure could give the highest and the lowest optimal payoff as the network varies.

2.5 Numerical analysis

In this section, we consider 4 different network structures: no network, circle/loop, star and complete network (see Figure 2.1). A no network is a situation in which no agent connects to any other agents. The circle/loop and complete network are symmetric network where each agent in the circle links to two other agents near-by and each agent in the complete links to every other agent. A star network is a network where one agent in the center links to all other agents. In this case, complete graph is the most strongly connected network in which each agent is connected to every other agent (i.e., each node has $N-1$ number of direct links. It is important to note that in the case of complete network, the number of direct links will increase as the network size increases, while in the circle network, each agent always has two direct neighbors and the number of direct links will not increase when there is an increasing in network size. In the case of the star network, only the central agent has an increasing direct network connections as the network size increases, while other agents have only one direct neighbor.



(a) No network **(b)** Star **(c)** Circle **(d)** Complete

Figure 2.1: The four different network structures.

We suppose that all the networks have 5 agents (i.e., a network of 5 agents). We consider that each agent can make an effort x_i ranging from 0 to 1, which are the 0% and 100% effort (i.e., $x_i \in [0,1]$). This means that the effort's capacity $\bar{x} = 1$, i.e., no one can make an effort higher than effort's capacity of 100%. Since by assumption that $X \leq \frac{a}{2b}$, if we let $a = 1$ for simplicity, then we choose $b = 0.1$ because $b \leq \frac{a}{2\bar{X}} = 0.1$. It should be noted that the parameter assumption of b is also satisfied the condition $X \leq \frac{a}{b}$.

Table 2.1: Parameter assumptions.

Parameter values
Agent i's effort: $x_i \in [0, \bar{x}]$ with $\bar{x} = 1$.
Parameters of the effort function $f(X) = aX - bX^2$: $a = 1$ and $b = 0.1$.
Extraction cost parameter: $\gamma = 0.8$.
Ability parameter: η_i is uniformly distributed in $[0, 0.5]$. In the numerical simulation, we have $\boldsymbol{\eta} = (0.1437, 0.3941, 0.2044, 0.4415, 0.4702)$.
Assimilation comparison parameter: δ_i is uniformly distributed in $[-0.2, -0.1]$. In the numerical simulation, we have $\boldsymbol{\delta} = (-0.1886, -0.1377, -0.1390, -0.1376, -0.1139)$.
Number of agents per network: $N = 5$.

The ability parameter is uniformly distributed ranging from 0 to 0.5. Thus, we have $E(\eta_i) = 0.25$. For the extraction cost, we refer to the Proposition 4 in which $\gamma \geq \frac{a+E(\eta)}{2x} - \frac{(N+1)b}{2}$ for $x > \hat{x}$. Thus, we choose $\gamma = 0.8$ since from the previous condition, we have $\gamma > 0.59$ for $x > 0.5$. From the KKT condition (Case 2.a), the over-exploitation problem will happen if $\gamma \leq 0.325$. The comparison parameter also is uniformly distributed ranging from -0.2 to -0.1 for the case of assimilation in comparison ($\delta_i < 0$). Our strategy is to choose a low comparison parameter in the first step and then increase both comparison parameter to observe their impacts on agent's behavior. The parameter assumptions are summarized in Table 2.1.

2.5.1 Nash equilibrium level of effort

From our parameter assumptions, we can simply calculate the interior equilibrium extraction effort for a given network structures. Figure 2.2 shows the results of the Nash equilibrium for 4 different types of network (i.e., no network, circle, star and complete network).

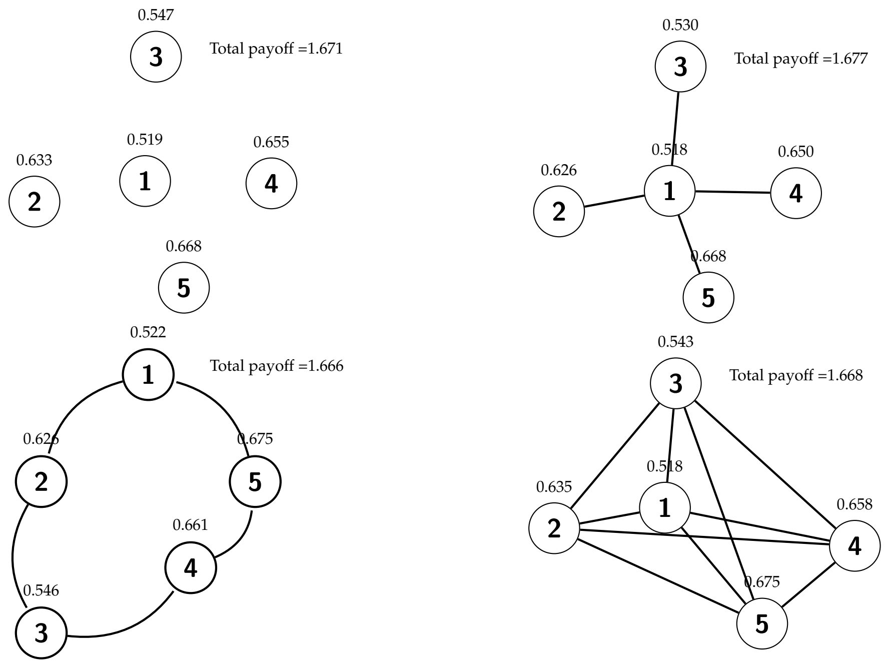


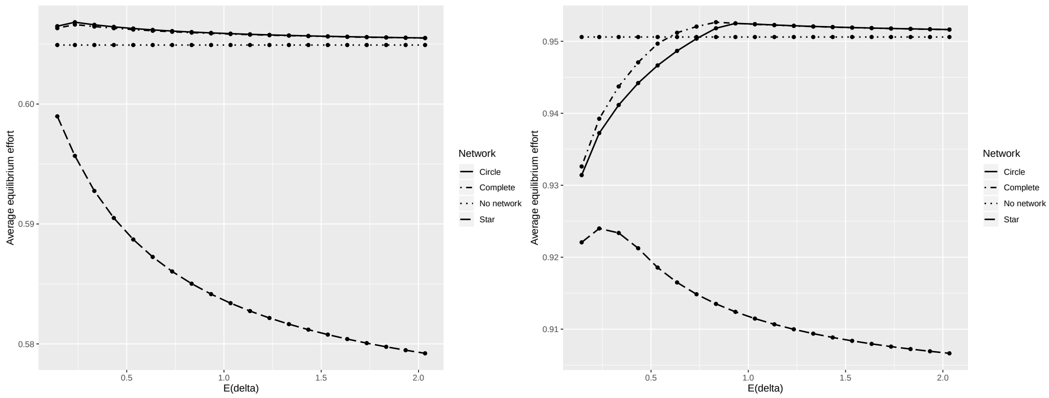
Figure 2.2: Nash equilibrium in 4 different networks.

The results of the case without network in Figure 2.2 confirm our proposition 1 that a higher ability agent would put more effort in extracting the common resource than lower ability one. It should be noted that the matrix $\boldsymbol{\eta} = (0.1437, 0.3941, 0.2044, 0.4415, 0.4702)$ (see Table 2.1) suggests that agent 1 is the one has lowest ability in the group, while agent 5 is the highest ability agent. Thus, agent 5 is the one who put highest effort in extracting the common resource.

In the presence of network, the story becomes much more interesting since agents take their direct neighborhood extraction into account when making their decisions. The social comparison is assimilation in comparison which means that agents try to imitate the behaviors of their direct neighbors and make a decision as close as to the average direct neighborhood decisions. It should be noted that from the assumptions, we have $\boldsymbol{\delta} = (-0.1886, -0.1377, -0.1390, -0.1376, -0.1139)$ (see Table 2.1) which suggests that agent 1 who has lowest ability but (s)he is the one who care most about his/her direct neighborhood behaviors, while agent 5 cares about his/her direct neighbors compared to other agents. We observe in Figure 2.2 that network plays a role in shaping the social comparison since there are differences in agents' behaviors and total payoff in different networks. In order to investigate deeply the impact of social comparison and networks, we let the comparison parameter varies and look at the equilibrium outcomes in different networks. This will be discussed shortly in next subsection.

2.5.2 Role of social comparison in networks

In this section, we separate our discussions into two different cases: with/without over-exploitation problem. In the first case, we consider that there is no over-exploitation with $\gamma = 0.8$. In this case, agents would have no incentive to put maximum efforts in extracting the resource because of the sufficiently high extraction cost. In the second case, we assume that there will be the over-exploitation of CPR with $\gamma = 0.4$. In this case, without any invention (or policy), each agent would extract the CPR with the maximum effort's capacity ($\bar{x} = 1$). Figure 2.3 shows the average equilibrium extraction in the situation with/without over-exploitation problem.



(a) $\gamma = 0.8$ **(b)** $\gamma = 0.4$

Figure 2.3: Average Nash equilibrium extraction with different degree of social comparison for $\boldsymbol{\eta}$ = $(0.143, 0.394, 0.204, 0.441, 0.470)$**.**

Sub-figure (a) in Figure 2.3 shows that the assimilation in comparison cannot help to encourage the resource conservation as we expected when agents are in the decentralized networks (i.e., circle and complete network). This result can be justified by Proposition 3 because in the decentralized network, we often have $\theta_i^* \to 0$ as $E(\delta_i)$ increases. As a result, a more increasing in $E(\delta_i)$, a more likely that there is a over-exploitation of the CPRs. However, in the centralized network (i.e., star network), agents seem to be motivated by reducing their extraction as the effected assimilation effect $E(\delta_i)$ increases because agent 1 who is the center of the star has the lowest ability η and thus $\theta_i^* = x^* - \bar{x}^*_{N_i(g)} > 0$ (see Proposition 3).

As previously mentioned, in the case of no over-exploitation problem, it is not necessary to introduce the social comparison to motivate the resource conservation because there is a sufficiently high extraction cost. Thus, it would be more interesting to investigate the role of social comparison in the case of over-exploitation problem. In the case of over-exploitation of the CPRs, all agents would put maximum effort to extract the resource. By setting the extraction cost $\gamma = 0.4$, we observe that in case of no social comparison, the average extraction equals to 0.9505 (i.e., agents put 95% of their effort's capacity in extracting the resource). It should be noted that the maximum effort's capacity is each agent choosing $x = 1.0$ (i.e., 100% effort). We observe that there is a possibility to encourage the resource conservation with a relatively small $E(\delta_i)$. However, the over-exploitation problem can be becoming worse in the decentralized networks as $E(\delta)$ increases (see Sub-figure (b) in Figure 2.3). This is because we always have in assimilation in comparison the property that $\theta_i^* \to 0$ as $E(\delta_i)$ increases. Therefore, a good strategy is to keep the comparison parameter as small as possible in order to encourage the common resource conservation.

By comparing between the circle and complete network, we observe that network with more connections (i.e., complete network) performs slightly worse than the one with fewer connections in encouraging the conservation of the CPRs. This result is straightforward because in the case of complete network, all agents are linked together and thus they are more likely to mitigate others' behaviors than the circle network where agents compare their behaviors to only two direct neighbors.

It is important to note that both circle and complete network are decentralized network and each agent in these networks has a same number of connections, while the star is a centralized network which represents a real situation in which there is one central agent (i.e., a leader) who plays a key role in maintain the connections among agents in the network. We observe that the star network results in the highest total payoff with lower level of extraction compared to other types of network. This is because every agent in the star connects to only the center and the central agent is the one who has lowest ability in extracting the common resource. It should be noted that in our simulation the center of the star is one has lowest ability and thus put lowest effort in extracting the common resource. Thus, this leads to a reduction of resource extraction of the whole network. On the other hand, if we assume that the center in star is the one with highest ability, then the over-exploitation problem will be more likely to happen (Figure 2.4 in Appendix B). Therefore, it is interesting for future study to investigate in depth using key players in the network to encourage individual behavioral change toward environmental sustainability (Borgatti, 2006; Patacchini and Zenou, 2009).

2.6 Conclusion and discussion

In our study, we investigate the role of assimilation in social comparison in the network-based common pool resource game. We assume that agents are in a specific network and they take their direct neighborhood actions into account when making their decisions (i.e., social comparison in networks). We suppose that there is an assimilation in comparison which means that ones change their behaviors to minimize the difference/distance between them and others. We find that in the case of empty network (i.e., no links between agents), a sufficiently high extraction cost is necessary to avoid the over-exploitation of a common pool resource. This is because in the case of empty network, no agents will take any other behaviors into their decision-making processes, thus as the cost of extracting the resource reduces, the tragedy of common is more likely to happen since all agents would have incentive to put as much as possible their efforts to extract the common good.

In the presence of networks, the assimilation in social comparison can help to shift individual behaviors in the way that promotes the conservation of the CPRs. However, since agents are heterogeneous in their ability to extract the common resource (i.e., with the same amount of effort invested in extracting the CPR, one who has higher ability could earn higher benefit than others), a network with more connections would lead to a more serious exploitation problem than the one with fewer connections. This is because a more the agents are linked to each other, they are more likely to mitigate others' behaviors. As a result, agents would have higher possibility to extract more resource if they observe that their neighbors or friends are doing so. Therefore, we suggest that policymaker should carefully take the different types of network structure into account before implementing any policy (or intervention) that promotes the assimilative comparison.

Moreover, our results also suggest that promoting the assimilation in the centralized networks (like a star network) is better than the decentralized one (like a circle or a complete network) in encouraging the resource conservation. More specifically, we can promote the social comparison in the decentralized network but it is important to keep a relatively low assimilation effect in order to encourage to resource conservation. Thus, a good way to motivate the CPR conservation is to promote the assimilation in the centralized network. However, as previously mentioned, how effective the social comparison in promoting the CPR conservation in star network depends on the performance or ability of the central agent. Therefore, it is also important to provide information about how important the resource conservation to the key player in the network (e.g., a central player in the star network) in order to more effectively incentivize the resource conservation.

This analysis has several shortcomings which could be addressed by future research. Firstly, in this study, we only take into account the exogenous network which agents cannot choose who will be their neighbors in the CPR game. An endogenous network of the CPR game could also be interesting to study. With the endogenous network, we can either use the static framework with the simultaneous move game in which agents choose his effort and the links at the same time or the dynamic game in which agents first choose his neighbors and then the optimal effort. Secondly, we do not explore the possibility of the contrast in comparison which agents have incentives to differentiate with their neighbors because no agent is willing to differentiate with others by extracting less the common resource since there is a “substractability" of the commons. However, the contrast in comparison will be interesting to be study if one can justify that there exists the case “doing worse, but feeling better" in extracting the common pool resource (Lockwood et al., 2004; Toma, 2013). Therefore, it is interesting that the future research could take this issue into consideration.

Bibliography

Arrow, K. (1970). Political and Economic Evaluation of Social Effects and Externalities. In *The Analysis of Public Output*, Chapter 1, pp. 1–30. National Bureau of Economic Research.

Barnes-Mauthe, M., S. Arita, S. Allen, S. Gray, and P. Leung (2013). The influence of ethnic diversity on social network structure in a common-pool resource system: Implications for collaborative management. *Ecology and Society 18*(1), 23.

Borgatti, S. P. (2006). Identifying sets of key players in a social network. *Computational & Mathematical Organization Theory 12*(1), 21–34.

Bromley, D. W. and M. M. Cernea (1989). *The Management of Common Property Natural Resources: Some Conceptual and Operational Fallacies*. World Bank Publications.

Burkart, J. M., E. Fehr, C. Efferson, and C. P. van Schaik (2007). Other-regarding preferences in a non-human primate: Common marmosets provision food altruistically. *Proceedings of the National Academy of Sciences 104*(50), 19762–19766.

Cárdenas, J. C., C. Mantilla, and R. Sethi (2015). Stable sampling equilibrium in common pool resource games. *Games 6*(3), 299–317.

Frey, B. S. and S. Meier (2004). Social comparisons and pro-social behavior: Testing “conditional cooperation" in a field experiment. *American Economic Review 94*(5), 1717–1722.

Gelcich, S., T. P. Hughes, P. Olsson, C. Folke, O. Defeo, M. Fernández, S. Foale, L. H. Gunderson, C. Rodríguez-Sickert, M. Scheffer, et al. (2010). Navigating transformations in governance of Chilean marine coastal resources. *Proceedings of the National Academy of Sciences 107*(39), 16794–16799.

Hardin, G. (1968). The tragedy of the commons. *Science 162*(3859), 1243–1248.

Isaac, R. M. and J. M. Walker (1988). Group size effects in public goods provision: The voluntary contributions mechanism. *Quarterly Journal of Economics 103*(1), 179–199.

Lockwood, P., D. Dolderman, P. Sadler, and E. Gerchak (2004). Feeling better about doing worse: Social comparisons within romantic relationships. *Journal of Personality and Social Psychology 87*(1), 80.

Mantilla, C. (2015). Communication networks in common-pool resource games: Field experimental evidence. *Journal of Economic Behavior & Organization 118*, 215–226.

Mussweiler, T., K. Rüter, and K. Epstude (2004). The ups and downs of social comparison: Mechanisms of assimilation and contrast. *Journal of Personality and Social Psychology 87*(6), 832.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Political Economy of Institutions and Decisions. Cambridge University Press.

Ostrom, E. (2008). The challenge of common-pool resources. *Environment: Science and Policy for Sustainable Development 50*(4), 8–21.

Ostrom, E., R. Gardner, and J. Walker (1994). *Rules, games, and common-pool resources*. University of Michigan Press.

Patacchini, E. and Y. Zenou (2009). Juvenile delinquency and conformism. *The Journal of Law, Economics, & Organization 28*(1), 1–31.

Pearce, D. W. and R. K. Turner (1990). *Economics of Natural Resources and the Environment*. Johns Hopkins University Press.

Poteete, A. R. and E. Ostrom (2004). Heterogeneity, group size and collective action: The role of institutions in forest management. *Development and Change 35*(3), 435–461.

Rustagi, D., S. Engel, and M. Kosfeld (2010). Conditional cooperation and costly monitoring explain success in forest commons management. *Science 330*(6006), 961–965.

Schweitzer, F., G. Fagiolo, D. Sornette, F. Vega-Redondo, A. Vespignani, and D. R. White (2009). Economic networks: The new challenges. *Science 325*(5939), 422–425.

Sethi, R. and E. Somanathan (1996). The evolution of social norms in common property resource use. *American Economic Review 86*(4), 766–788.

Toma, C. L. (2013). Feeling better but doing worse: Effects of Facebook self-presentation on implicit self-esteem and cognitive task performance. *Media Psychology 16*(2), 199–220.

Walker, J. M., R. Gardner, and E. Ostrom (1990). Rent dissipation in a limited-access common-pool resource: Experimental evidence. *Journal of Environmental Economics and Management 19*(3), 203–211.

Appendix A.1: Lemma 1 - Sufficient condition of optimality.

From the necessary condition from Equation (2.12), we have

$$\frac{\partial U_i}{\partial x_i} = f^{'}(X)\frac{x_i}{X} + f(X)\frac{x_{-i}}{X^2} - 2\gamma x_i + \eta_i + \frac{\partial I_i(x_i)}{\partial x_i}.$$

By taking the derivative of the above equation with respect to x_i, we have

$$\begin{aligned}
\frac{\partial^2 U_i}{\partial x_i^2} &= f^{''}(X)\frac{x_i}{X} + f^{'}(X)\left\{\frac{X - x_i}{X^2}\right\} + f^{'}(X)\frac{x_{-i}}{X^2} - f(X)\left\{\frac{2x_{-i}X}{X^4}\right\} - 2\gamma + \frac{\partial^2 I_i(x_i)}{\partial x_i^2} \\
&= f^{''}(X)\frac{x_i}{X} + f^{'}(X)\left\{\frac{2x_{-i}}{X^2}\right\} - f(X)\left\{\frac{2x_{-i}}{X^3}\right\} - 2\gamma + \frac{\partial^2 I_i(x_i)}{\partial x_i^2} \\
&= f^{''}(X)\frac{x_i}{X} + \left(f^{'}(X) - \frac{f(X)}{X}\right)\left\{\frac{2x_{-i}}{X^2}\right\} - 2\gamma + \frac{\partial^2 I_i(x_i)}{\partial x_i^2} \\
&= \frac{1}{X^2}\left\{f^{''}(X)Xx_i + 2x_{-i}\left(f^{'}(X) - \frac{f(X)}{X}\right)\right\} - 2\gamma + \frac{\partial^2 I_i(x_i)}{\partial x_i^2}.
\end{aligned}$$

Appendix A.2: Proposition 3 - Over-exploitation of the CPRs.

Let us recall Equation (2.16) such that:

$$f(X^*)\frac{x_i^*}{X^*} - \gamma x_i^{*2} + \eta_i x_i^* + \delta_i(x_i^* - \bar{x}^*_{N_i(g)})^2 \geq f(\bar{X})\frac{\bar{x}_i^c}{\bar{X}} - \gamma(\bar{x}_i^c)^2 + \eta_i \bar{x}_i^c.$$

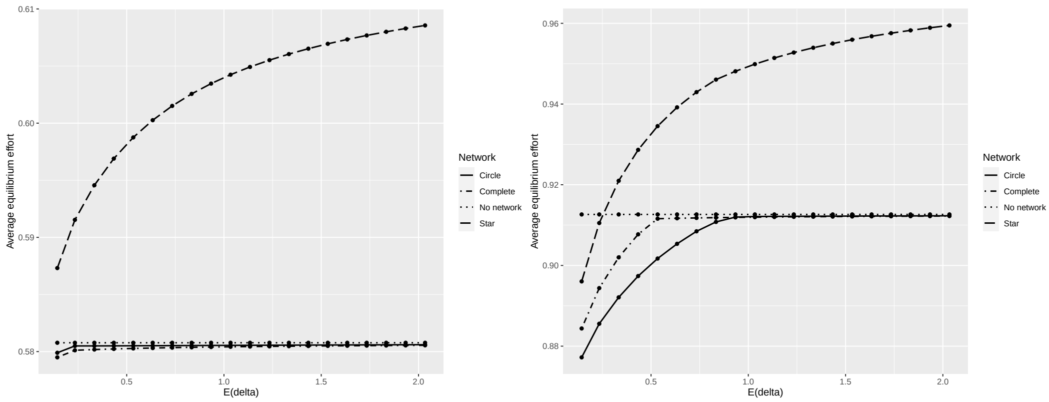
We denote that $\theta_i^* = x_i^* - \bar{x}^*_{N_i(g)}$. Since the functional form of $f(X)$ is known, and for any $X \neq 0$, we thus have

$$(a - bX^*)x_i^* - \gamma x_i^{*2} + \eta_i x_i^* + \delta_i(\theta_i^*)^2 \geq (a - b\bar{X})\bar{x} - \gamma \bar{x}^2 + \eta_i \bar{x}$$
$$(a + \eta_i)(x_i^* - \bar{x}) - \gamma(x_i^{*2} - \bar{x}^2) - b(X^* x_i^* - N\bar{x}^2) + \delta_i(\theta_i^*)^2 \geq 0.$$

Since we know that $x_i^{*2} - \bar{x}^2 = (x_i^* - \bar{x})(\bar{x} + x_i^*)$ and $x_i^* - \bar{x} \leq 0$, we therefore would have

$$\gamma x_i^* + \frac{b(X^* x_i^* - N\bar{x}^2) - \delta_i(\theta_i^*)^2}{x_i^* - \bar{x}} \geq a - \gamma\bar{x} + \eta_i.$$

Appendix B: Nash equilibrium extraction with different ability parameters.



(a) $\gamma = 0.8$ **(b)** $\gamma = 0.4$

Figure 2.4: Average Nash equilibrium extraction with different degree of social comparison for $\boldsymbol{\eta}$ = $(0.477, 0.468, 0.119, 0.127, 0.195)$.

Chapter 3

Common pool resource game on endogenous network[1]

3.1 Introduction

In the 20th century, an ecologist, Garrett Hardins developed the theory of the tragedy of commons which helps to explain the mass exploitation of our environmental resources (Hardin, 1968). In his study, he argued that because of the "subtractability" property[2] of the common pool resources (henceforth CPRs), it is difficult to prevent people to subtract units from a common pool (e.g., forests, oceans, fishing pounds and even atmosphere) and thus makes the management of CPRs becoming much more complex. For example, the world oceans are an example of a global common that are exploited by countries and corporations seeking to extract maximum personal gain for this common area (Ostrom, 2008).[3] So following Hardin's theory, if every individual acts to ensure maximum personal gain without regarding to the carrying capacity of a common resource, the common will reach its maximum capacity and collapses (i.e., problem of the tragedy of common). This can happen in the form of exponential global warning trends (Broecker, 1975; Hansen and Sato, 2001; Payne and Smith, 2017).

Over the last decade, the problem of the tragedy of common has captured much more attention of research scholars. A majority of studies supported the theory of Hardin (1968) by showing that in the situation of resource scarcity, an additional resource extraction would cause a negative externality for others. As a result, if self-interest individuals maximize their resource extraction by equalizing their marginal personal gains with the marginal cost of extraction, then this would undoubtedly lead to the over-exploitation of

[1] This chapter is based on Tiet T. (2020), Common pool resource game on endogenous network.

[2] The "subtractability" property means an additional common resource consumption would lead to a decrease the available resources for others (Hardin, 1968).

[3] There are internally respected maritime boundaries that extend 200 miles out from the shore but anything part that is considered high seas and it is governed by no country. These maritime boundaries only extend to cover a small portion in the ocean and everything else is highly vulnerable to exploitation (Hinrichsen, 2016).

the common (Bromley and Cernea, 1989; Pearce and Turner, 1990). Thus, the inefficiently high level of resource extraction could threaten the long-term sustainability of the common as well as the long-term utility for all the individuals (Sethi and Somanathan, 1996). The Chilean abalone war, in which the competition between poachers and fisherman in Chile to harvest abalone (the world's most valuable shellfish) leads to an armed conflict, is a good example for the problem of the tragedy of common (Gelcich et al., 2010).

However, several studies, especially Ostrom et al. (1994), supported the possibility of cooperation among individuals in the management of CPRs. In their study, Ostrom et al. (1994) have shown the possibility and explained theoretically how to achieve a successful endogenous management of CPRs. In her book, Ostrom (1990) cataloged several examples in which communities have successfully managed the CPRs without any help of the central government, from 16th century Alpine shepherds managing grazing lands to the year of 1980s Japanese villages managing communal forests. Ostrom's work was seeking to uncover the rules of engagements that promote cooperation among self-interested individuals in social dilemmas. Following the study of Ostrom, Chaudhuri (2011); Bowles and Gintis (2011) and many others, suggested how human cooperation in managing the common could emerge and persist under stable institutions.

In recent years, numerous researches indicated that promoting social norms of sustainable resource use can help to discourage the incentive for over-exploitation of the CPRs (Sethi and Somanathan, 1996; Tavoni et al., 2012). In their study, Sethi and Somanathan showed that individuals are more likely to cooperate by restraining their levels of resource extraction if there exist a sanctioning in the way that uncooperative individuals could be sanctioned by others. Sanctions could help to improve the cooperation and norms of behavior can persist by restraining the use of the common goods. In other words, when individuals could monitor and enforce behavior within their groups to prevent the over-exploitation of the common resource, the peer monitoring and sanctioning could help to promote the coordination in individuals' decisions (De Geest et al., 2017).

In addition to norms, several existing studies suggested that network (i.e., network structure or social structure) could also play an important role in mitigating the over-extraction problem of the CPRs, especially when the populations dependent highly on the common property, have close proximity and enduring social ties (Cárdenas et al., 2015). According to the theory of pro-social behavior, individuals who have a strong social preference would concern more about others' well-being are willing to help others and desires to uphold ethical norms (Frey and Meier, 2004). Several theoretical studies suggested that network plays a key role in encouraging public good contribution (Bramoullé et al., 2014;

Galeotti et al., 2010; Bramoullé and Kranton, 2007), promoting pro-social behavior (Fischbacher and Gachter, 2010; Frey and Meier, 2004), and encouraging informational sharing (Masuda et al., 2018; Mantilla, 2015). Besides these theoretical evidence, behavioral economic experiments have shown that informational sharing through a social network could help restrain the resource extraction (Mantilla, 2015; Barnes-Mauthe et al., 2013). In their study, Barnes-Mauthe et al. (2013) showed that fisheries in a network share information with each others in order to cooperatively reduce fish by-catch rate. In the study of Mantilla (2015), they found that cooperation exists in the CPR game and network structure plays a key role in reducing the aggregate extraction level of the CPR. Therefore, network would be a good starting point to explain how could individuals behave pro-environmentally by conserving a common good.

While the network model has been widely studied in the literature of public good game (i.e., individual's contributions to public goods), a handful of theoretical evidence has been found in studying the impact of social incentives through networks on individuals' behaviors in the literature of common pool resource game. Moreover, when a network structure is not given (i.e., not fixed or exogenous), each individual could decide to whom he or she would like to initiate a connection (i.e., a link with). In this case, individual behavior would not only influence by the network but also have impacts on the network structure (i.e., network formation). Thus, in this study, we explore how social influence through endogenous network can help to promote the sustainable consumption of the CPRs. In this study, we use the static framework of Nash equilibrium to examine the outcome of the CPR game under assumption of existing network structure (i.e., agents choose the number of neighbors to link with) and social influence (agents are influenced by their direct neighborhood behaviors). We assume in our model that individuals will take their neighborhood (i.e., agent's direct neighbors in the network) behaviors into their decision-making process. Since efforts and network connection (i.e., number of network links that agents have) are costly, each agent has to simultaneously decide how much effort to put in extracting the common resource as well as how many neighbors to make a connection to in order to maximize his or her personal utility.

We aim to answer two main questions. First, how could social influence through network promote the individual behaviors toward sustainable consumption of a common pool resource? Second, what is the relationship between the network connection and the extraction of the common resource? Finally, will the CPR game locally stable as network size, cost of linking and social influence parameter vary. Our results suggest that social influence through network could help to incentivize individuals to reduce their effort in extracting a common good. In particular, in presence of social influence, it is possible to shift agents' behaviors from strategic substitute to strategic complementarity and thus it could help to solve the social dilemma in the common pool resource game. Our results also suggest that there is a negative relationship between network connection and agents' extraction efforts. However, it is necessary to have either a low cost of linking (i.e., a cost for initiating a link with other agent) or a strong social influence to encourage agents to initiate links with others in order to promote the resource conservation. Moreover, depending on the different parameter of the linking cost and social influence, the CPR game would exist a locally stable equilibrium. More importantly, we find that when there are more than six agents competing in harvesting a common resource, the CPR game will become locally unstable (Saijo et al., 2017). Therefore, we suggest that policymaker or future research should carefully take the network size into account into consideration before designing a program which uses social influence through network to encourage individuals to conserve the common resource.

The paper proceeds as follows: Section 2 studies the common resource game with social influence through network, in which we investigate how individual agent's behavior change corresponds to their direct neighborhood behaviors and the relationship between individual agent's behavior and his or her network connection. In this section, we also compute the Nash equilibrium with the assumptions about the functional form of the effort function and social influence. In Section 3, we discuss the welfare analysis. Section 4 summarizes the results of our numerical analysis. Section 5 is the local dynamic in which we study the equilibrium dynamics with the different parameters of the model. The conclusion and discussion are reported in section 6.

3.2 A common pool resource game

3.2.1 Setup

Let consider that there are N agents, a typical agent is denoted by i. Agents are connected by a network $(N, \mathbf{G})$, where $\mathbf{G}$ is an $N \times N$ adjacency matrix, its element g_{ij} represents the relationship between i and j. In the network of i, denoted N_i, $g_{ij} = 1$ if $j \in N_i$ and $g_{ij} = 0$ if $j \notin N_i$. For simplicity, we assume that each agent is represented by a node in the network and there is a random network where nodes can connect and be connected to every other nodes. We also suppose that the network is *undirected* which requires that $g_{ij} = g_{ji}$, which means that if i links to j, j will link to i. The set of nodes that i is linked to is called the neighbor of a node i: $N_i(g) = \{j \in N_i \setminus i : g_{ij} = 1\}$ and $k_i = \frac{1}{N-1}|N_i(g)|$ is the network connection (i.e., fraction of friends or neighbors) with $|N_i(g)|$ be agent i's total number of direct connections/links (Schweitzer et al., 2009).

Each agent will face a decision problem of how to optimally allocate his or her effort x_i to extract the resources and choose optimal network connection k_i. Each agent's objective is to simultaneously choose x_i and k_i to maximize his or her utility function. There exists the extraction cost $\gamma > 0$ which incurs in extracting the resources. We assume that the total effort function $f(X)$ is concave, in which $f(0) = 0$, $f(X) > 0$ if $X > 0$, $f'(X) > 0$ and $f''(X) < 0$, where $X = \sum_i x_i$. According to "substractability" property of the CRPs, a resource share extracted by agent i which is the proportion of effort that i make in extracting the resources with respect to the total sum of all agents' effort, is calculated by $\frac{x_i}{x_i + x_{-i}}$ where x_{-i} is the sum of all agents' efforts excluded i. Depending on his or her extraction effort, each agent would gain a benefit which equals to $f(X)\frac{x_i}{x_i + x_{-i}}$. This indicates that if one puts higher effort in extracting the common resource, others would suffer a benefit loss from the CPRs (i.e., "substractability" property).

Regarding the networks, agent i has to pay a cost $c(k_i)$ for the total number of neighbors that i connects to, which is also known as the linking or connection cost. This linking cost could be interpreted as the time or money spent for social activities (i.e., time spent socializing). Agents will form a link to others if there is a benefit gained from the link, which could be interpreted as the social approval from and social comparison with others in the network (Holländer, 1990; Bandura and Jourden, 1991; Rege and Telle, 2004). We denote the benefit function as $B(x_i, x_{N_i(g)}, k_i)$, where $x_{N_i(g)} = \{x_j : j \in N_i(g)\}$. We also have $\delta B(x_i, x_{N_i(g)}, k_i)$, represented for the impact of the benefit function on the utility, where δ represents the degree of this influence (we call δ as the social influence parameter). A higher social influence parameter means that a higher value of δ induces a higher the network benefit. To put it simply, for a given extraction effort x_i, agent i would prefer the network connection k_2 to k_1 for $k_2 > k_1$ if and only if $U(x_i, k_2) > U(x_i, k_1)$. Thus, since the extraction effort x_i is given, we have agent i prefers k_2 to k_1 if and only if the following condition is satisfied $\delta B(x_i, x_{N_i(g)}, k_2) - c(k_2) > \delta B(x_i, x_{N_i(g)}, k_1) - c(k_1)$ for $k_2 > k_1$.

3.2.2 Model

In this study, we investigate the individual behaviors in a CPR game by taking into account the endogenous network as previously mentioned.[4] In particular, agents have to pay a cost in order to initiate a link with other agent. Agents benefit from their direct neighborhood

[4] In the spirit of Sethi and Somanathan (1996), agent i's payoff function in the absence of network and social comparison is defined by

$$U_i(x_i, x_j) = f(x_i + x_{-i})\frac{x_i}{x_i + x_{-i}} - \gamma x_i$$

Following Sethi and Somanathan (1996), in this model, we are always facing the over-exploitation problem of common pool resource: each agent maximizes her payoff by extracting as much as possible. In their paper, the authors also study a model of CPR game with sanctioning.

$$U_i(x_i, x_j) = f(x_i + x_{-i})\frac{x_i}{x_i + x_{-i}} - \gamma x_i - \alpha k_i - \beta l_i$$

In this model, each agent can punish and be punished by any of others. The author argued that sanctions could improve the cooperation in social dilemmas, but they impose a high social cost until there is no threat of non-cooperative behavior.

connection $B(x_i, x_{N_i(g)}, k_i) > 0$. Thus, for given x_{-i},we have the agent i's utility function as follows:

$$\begin{aligned} & U_i(x_i, k_i) = f(X)\frac{x_i}{X} - \gamma x_i^2 - c(k_i) + \delta B(x_i, x_{N_i(g)}, k_i) \\ \text{s.t} \quad & x_i \leq \bar{x}, \quad x_i \geq 0, \quad 0 \leq k_i \leq 1 \end{aligned} \tag{3.1}$$

where, $X = x_i + \sum_{j \neq i} x_j$ and $\bar{x}$ is the effort's capacity.
From the optimization problem 3.1, we have the following Lagrangian.

$$\begin{aligned} \mathcal{L}(x_i, k_i) = {} & f(X)\frac{x_i}{X} - \gamma x_i^2 - c(k_i) + \delta B(x_i, x_{N_i(g)}, k_i) \\ & - \lambda_1(x_i - \bar{x}) - \lambda_2(k_i - 1) + \lambda_3 x_i + \lambda_4 k_i \end{aligned} \tag{3.2}$$

Karush-Kuhn-Tucker conditions

In the spirit of the Karush-Kuhn-Tucker (KKT) theorem, we have

$$\frac{\partial \mathcal{L}(x_i, k_i)}{\partial x_i} = 0 \quad \text{and} \quad \frac{\partial \mathcal{L}(x_i, k_i)}{\partial k_i} = 0, \tag{3.3}$$

$$\lambda_1(x_i - \bar{x}) = 0, \qquad x_i \leq \bar{x}, \tag{3.4}$$

$$\lambda_2(k_i - 1) = 0, \qquad k_i \leq 1, \tag{3.5}$$

$$\lambda_3 x_i = 0, \qquad x_i \geq 0, \tag{3.6}$$

$$\lambda_4 k_i = 0, \qquad k_i \geq 0, \tag{3.7}$$

$$\lambda_m \geq 0, \; m = \{1, 2, 3, 4\}. \tag{3.8}$$

Concerning the complementary slackness conditions 3.6 and 3.7 which are $\lambda_3 x_i = 0$ and $\lambda_4 k_i = 0$, we consider four following cases:

Case 1. *Both $x_i \geq 0$ and $k_i \geq 0$ are binding.*

In this case, with these both constraints are binding, agents will have zero utility with $U_i(0, x_j, 0) = 0$ since $B(0, x_{N_i(g)}, 0) = 0$. Thus, all agents would have zero utility if the both constraints are binding and a corner solution $(\underline{x}^c, \underline{k}^c) = (0, 0)$.

Case 2. *The constraint $k_i \geq 0$ is binding and $x_i \geq 0$ is not binding.*

In this case, we have $B(x_i, x_{N_i(g)}, 0) = 0$ and $\gamma k_i^2 = 0$, for $k_i = 0$. Since the constraint $x_i \geq 0$ is not binding, we need $\lambda_3 = 0$ for the complementary slackness condition 3.6 to be satisfied. Thus, we have a simple CPR optimization problem which has been studied in the literature (Sethi and Somanathan, 1996).

$$\max_{x_i} U_i(x_i) = f(X)\frac{x_i}{X} - 2\gamma x_i,$$
$$\text{s.t} \qquad x_i \leq \bar{x}.$$

And then, from the KKT conditions, we would have

$$\frac{\partial \mathcal{L}(x_i)}{\partial x_i} = f^{'}(X)\frac{x_i}{X} - f(X)\frac{x_{-i}}{X} - \gamma x_i^2 - \lambda_1 = 0,$$
$$\lambda_1(x_i - \bar{x}) = 0, \qquad \lambda_1 \geq 0, \qquad \text{and} \qquad x_i \leq \bar{x}.$$

where, $x_{-i} = \sum_{j \neq i} x_j$.
Thus, we have a corner solution in which $(\underline{x}^c, \underline{k}^c) = (\underline{x}^c, 0)$ and $\underline{x}^c$ is the solution of the following equation $[f^{'}(X) - (N-1)f(X)]\frac{x}{X} - 2\gamma x = \lambda_1$, for $\lambda_1 \geq 0$.

Case 3. *Condition $x_i \geq 0$ is binding and $k_i \geq 0$ is not binding.*

In this case, agent i chooses $x_i = 0$ and $k_i > 0$. Then, agent i has to choose only k_i that maximize the following optimization problem.

$$\max_{k_i} U_i(0, k_i) = -c(k_i) + \delta B(0, x_{N_i(g)}, k_i),$$
$$\text{s.t} \qquad k_i \leq 1, \quad x_i \leq \bar{x}.$$

We observe that the condition $x_i = 0$ holds if $U_i \geq 0$. Thus, we need $\delta B(0, x_{N_i(g)}, k_i) \geq c(k_i)$. Let us assume that $\delta B(0, x_{N_i(g)}, k_i) \geq c(k_i)$, then we have the Lagrangian as follows:

$$\mathcal{L}(k_i) = -c^{'}(k_i) + \delta B(0, x_{N_i(g)}, k_i) - \lambda_1(x_i - \bar{x}) - \lambda_2(k_i - 1).$$

Taking the first order condition with respect to k_i, we have

$$\frac{\partial \mathcal{L}(k_i)}{\partial k_i} = -c^{'}(k_i) + \delta \frac{\partial}{\partial k_i} B(0, x_{N_i(g)}, k_i) - \lambda_2 = 0.$$

Thus, under the condition $\delta B(0, x_{N_i(g)}, k_i) \geq \nu k_i^2$, we have a corner solution $(x^c, k^c) = (0, k^c)$, in which k^c is the solution of the equation $-c^{'}(k_i) + \delta\frac{\partial}{\partial k_i}B(0, x_{N_i(g)}, k_i) - \lambda_2 = 0$ for $\lambda_2 \geq 0$.

Case 4. *Both conditions $x_i \geq 0$ and $k_i \geq 0$ are not binding.*

In this case, in order for the slackness condition 3.6 and 3.7 to be satisfied, we need λ_3 and λ_4 equal to zero. Now, in Case 4, concerning the complementary slackness conditions

3.4 and 3.5 which are $\lambda_1(x_i - \bar{x}) = 0$ and $\lambda_2(k_i - 1) = 0$, by the same logic, we also consider the four following cases.

Case 4.a. *Both constraints $x_i \leq \bar{x}$ and $k_i \leq 1$ are not binding.* Thus, we need $\lambda_1 = 0$ and $\lambda_2 = 0$ in order for the complementary slackness conditions 3.4 and 3.5 to be satisfied. And similarly for the other three cases.

Case 4.b. *The constraint $x_i \leq \bar{x}$ is binding and $k_i \leq 1$ is not binding.* Thus, $\lambda_1 > 0$ and $\lambda_2 = 0$.

Case 4.c. *The constraint $x_i \leq \bar{x}$ is not binding and $k_i \leq 1$ is binding.* Thus, $\lambda_1 = 0$ and $\lambda_2 > 0$.

Case 4.d. *Both constraints are binding which is $x_i = \bar{x}$ and $k_i = 1$.* In this case, we need both λ to be strictly positive, $\lambda_1 > 0$ and $\lambda_2 > 0$. Thus, the corner solution is $(x^c, k^c) = (\bar{x}, 1)$.

We focus our investigation on Case 4.a that the both slackness conditions are not binding, $x_i - \bar{x} < 0$ and $k_i - 1 < 0$. This a case that agents' efforts cannot reach the maximum effort's capacity and no agent can link to every other agents in the network. In order for the complementary slackness conditions 3.4 and 3.5 to be satisfied, we need $\lambda_1 = \lambda_2 = 0$. Then, in this case, we can write the KKT conditions as follows.

$$\frac{\partial \mathcal{L}(x_i, k_i)}{\partial x_i} = f^{'}(X)\frac{x_i}{X} + f(X)\frac{x_{-i}}{X^2} - 2\gamma x_i + \delta \frac{\partial}{\partial x_i} B(x_i, x_{N_i(g)}, k_i) = 0, \tag{3.9}$$

$$\frac{\partial \mathcal{L}(x_i, k_i)}{\partial k_i} = -c^{'}(k_i) + \delta \frac{\partial}{\partial k_i} B(x_i, x_{N_i(g)}, k_i) = 0. \tag{3.10}$$

Thus, the KKT condition is necessary condition for the maximization problem.

Sufficient condition for optimality

In order to ensure the existence of a maximum, the Hessian matrix has to be negative definite. Thus, the following Hessian second order sufficient condition must be hold: $H_1 = \frac{\partial^2 U_i}{\partial x_i^2} < 0$ and $H_2 = \frac{\partial^2 U_i}{\partial x_i^2}\frac{\partial^2 U_i}{\partial k_i^2} - \left(\frac{\partial^2 U_i}{\partial x_i \partial k_i}\right)^2 > 0$. We denote that $B_i = B(x_i, x_{N_i(g)}, k_i)$. Following the Hessian sufficient condition, we have

$$H_1 = \frac{\partial U_i^2}{\partial^2 x_i} = \frac{1}{X^2}\left\{f^{''}(X)Xx_i + 2x_{-i}\left(f^{'}(X) - \frac{f(X)}{X}\right)\right\} - 2\gamma + \delta\frac{\partial^2 B_i}{\partial x_i^2}.$$

Since we have $x_i, x_{-i} \geq 0$, $f^{''}(X) < 0$ and $f^{'}(X)X - f(X) < 0$ because $f(x)$ is a concave function, the condition $H_1 < 0$ if we have

$$\frac{\partial^2 B_i}{\partial x_i^2} \leq 0$$
$$\text{or} \quad 0 < \frac{\partial^2 B_i}{\partial x_i^2} \leq \frac{1}{\delta} \left| \frac{1}{X^2} \left\{ f^{''}(X)Xx_i + 2x_{-i} \left(f^{'}(X) - \frac{f(X)}{X} \right) \right\} \right|.$$

Now, we have the condition $H_2 = \frac{\partial^2 U_i}{\partial x_i^2}\frac{\partial^2 U_i}{\partial k_i^2} - \left(\frac{\partial^2 U_i}{\partial x_i \partial k_i}\right)^2 > 0$. This condition suggests that $H_2 > 0$ if we have

$$\frac{\partial^2 U_i}{\partial k_i^2} < 0 \quad \text{and} \quad \frac{\partial^2 U_i}{\partial x_i^2}\frac{\partial^2 U_i}{\partial k_i^2} > \left(\frac{\partial^2 U_i}{\partial x_i \partial k_i}\right)^2.$$

Note that we have $\frac{\partial^2 U_i}{\partial k_i^2} = -c^{''}(k_i) + \delta \frac{\partial^2 B_i}{\partial k_i^2}$, where $B_i = B(x_i, x_{N_i(g)}, k_i)$.

The slope of the best response function

Now we examine the relationship between x_i and x_{-i}, which is known as the slope of the best response function. Let $U_x = \frac{\partial U_i}{\partial x_i}$ and $U_k = \frac{\partial U_i}{\partial k_i}$. Following the theorem of implicit function (Chiang, 1984), we have

$$U_{xx}\frac{\partial x_i}{\partial x_{-i}} + U_{xk}\frac{\partial k_i}{\partial x_{-i}} + U_{xx_{-i}} = 0$$
$$U_{kx}\frac{\partial x_i}{\partial x_{-i}} + U_{kk}\frac{\partial k_i}{\partial x_{-i}} + U_{kx_{-i}} = 0$$

Solving these system equations leads us to the following equation (proof in Appendix B):

$$\frac{\partial x}{\partial x_{-i}} = \frac{1}{\Delta}(U_{xk}U_{kx_{-i}} - U_{xx_{-i}}U_{kk})$$

where, $\Delta = U_{xx}U_{kk} - U_{xk}U_{kx}$ and $\Delta > 0$ by the sufficient condition for optimality.
Thus, we observe that $\frac{\partial x}{\partial x_{-i}} < 0$ if $U_{xk}U_{kx_{-i}} - U_{xx_{-i}}U_{kk} < 0$. On the other hand, if $U_{xk}U_{kx_{-i}} - U_{xx_{-i}}U_{kk} > 0$, then $\frac{\partial x}{\partial x_{-i}} > 0$. Therefore, we would have the strategic complementarity between x_i and x_{-i} if and only if $U_{xk}U_{kx_{-i}} - U_{xx_{-i}}U_{kk} > 0$.

3.2.3 Nash equilibrium extraction and network connection

In order to calculate explicit solution for the Nash equilibrium and the welfare analysis in the next section, we make some assumptions about the functional forms of the effort function and social influence through network.

Following the study of Walker et al. (1990) in limit-access common pool resource, we let $f(x) = ax - bx^2$ be the effort function, where $a \geq 0$ and $b \geq 0$. We can check that the function $f(x)$ satisfies our assumption.

$$f(x) \geq 0 \text{ if } x \leq \frac{a}{b}, \qquad f^{'}(x) = a - 2bx \geq 0 \text{ if } x \leq \frac{a}{2b} \qquad f^{''}(x) = -2b \leq 0.$$

For simplicity, we assume that the resource capacity is equal to $\bar{X}$. In the spirit of a "fair share" contribution theory (Gould, 1993), in situation of cooperation, we consider that each agent shares equally the resource, i.e., $\bar{x}_j = \bar{x}_i = \bar{x} = \frac{\bar{X}}{N}$. The over-exploitation problem would happen when all agents put more effort than their maximum effort (i.e., effort capacity) to extract the common resource. Thus, agent i's conservation effort could be calculated by $\bar{x}_i - x_i$. Agents, who conserve the resource, would be more likely to be friend with who also conserve the common good. We therefore have the network benefit function as follows: $B(x_i, x_j) = (\bar{x}_j - x_j)(\bar{x}_i - x_i)$ for any j in the network of i, $j \in N_i(g)$. This means that each agent would continue to conserve the resource as long as their neighbors doing so. Total benefit gained from all agent i's direct connection is defined as follows:

$$B_i = \sum_{j \in N_i(g)} (\bar{x}_j - x_j)(\bar{x}_i - x_i) = \sum_{j}^{N} g_{ij}(\bar{x}_j - x_j)(\bar{x}_i - x_i), \tag{3.11}$$

where, $g_{ij} = 1$ if there is a link between i and j. For instance, when $N = 2$ and $g_{ij} = 1$ (or $j \in N_i(g)$), we would have $B(x_i, x_j) = (\bar{x}_j - x_j)(\bar{x}_i - x_i)$ with $g_{ij} = 1$. The network benefit function suggests that each agent, who put effort in conserving the common resource, would also benefit from their direct neighborhood conservation efforts.

In addition to the network benefit, in order to form a link to other agents, each agents has to pay a unit cost ν which is assumed to be homogeneous across agents. Since agent i's network connection, k_i, is defined as a fraction of friends or neighbors, total connection cost or linking cost is then calculated as follows:

$$c(k_i) = \nu[(N-1)k_i]^2, \tag{3.12}$$

where, $N - 1$ is the total number of potential connections and $k_i = \sum_j^N \frac{g_{ij}}{N-1}$. For instance, in a network with only two agents i and j who are connected to each other, we have $c(k_i) = \nu$. However, if there are 5 agents connected to each others in a circle network, we have $c(k_i) = 4\nu$.

We now examine the outcome of the model with social influence through network under the assumption of effort and network benefit functional forms. Thus, we have to solve the following maximization problem:

$$\max_{x_i,k_i} U_i(x_i,k_i) = f(X)\frac{x_i}{X} - \gamma x_i^2 - \nu[(N-1)k_i]^2 + \delta\sum_j^N g_{ij}(\bar{x}_j - x_j)(\bar{x}_i - x_i) \quad (3.13)$$

s.t $\quad x_i \leq \bar{x}, \quad x_i \geq 0, \quad 0 \leq k_i \leq N-1,$

Sufficient condition for optimality

We could simply check that the condition $H_1 < 0$ is satisfied because

$$\frac{\partial B_i}{\partial x_i} = -\delta\sum_j^N g_{ij}(\bar{x}_j - x_j) \text{ and } \frac{\partial^2 B_i}{\partial x_i^2} = 0.$$

Additionally, the condition $H_2 > 0$ can be satisfied if we have $4(b+\gamma)\nu(N-1) > (\delta\phi_i)^2$, where $\phi_i = \bar{x}_{N_i(g)} - \tilde{x}_{N_i(g)}$ (see the proof in Appendix A).

Therefore, this result leads us to the following Lemma.

Lemma 1. The optimization problem has a maxima if and only if there exists ν such that

$$\nu > \frac{(\delta\phi_i)^2}{4(b+\gamma)}, \quad (3.14)$$

where, $\phi_i = \bar{x}_{N_i(g)} - \tilde{x}_{N_i(g)}$.

The result of Lemma 1 is complementary with our previous condition of the linking cost ν. As previously mentioned, in order for a link between i and j to be established, we need $\nu < \delta(\bar{x}_j - x_j)(\bar{x}_i - x_i)$ for $j \in N_i(g)$ and $g_{ij} = g_{ji} = 1$. Thus, Lemma 1 suggests that the linking cost ν needs to be lower than the benefit of the network link, but this cost cannot be too low. If the cost ν is lower than the threshold $\frac{\delta^2(\bar{x}_j - \tilde{x}_j)^2}{4(b+\gamma)}$ for $j \in N_i(g)$, then there will not exist any interior equilibrium solution because when the linking cost is very low, all agents would have incentive to initiate the links with all other agents as much as possible (i.e., they will all choose the corner solution such that $k^c = 1$).

The slope of the best response function

From the previous Section, we can examine the relationship between x_i and x_{-i} by checking the following condition: $U_{xx_{-i}}U_{kk} - U_{xk}U_{kx_{-i}} > 0$. If this condition is satisfied then the CPR game is strategic complementary $\frac{\partial x}{\partial x_{-i}} > 0$. From the utility function, we could simply get that

$$
\begin{aligned}
U_{xx_{-i}} &= -b + \delta k_i(N-1), \\
U_{kk} &= -2\nu(N-1)^2, \\
U_{xk} &= -\delta(N-1)(\bar{x}_{-i} - \tilde{x}_{-i}), \\
U_{kx_{-i}} &= -\delta(N-1)(\bar{x}_i - x_i).
\end{aligned}
$$

Thus, the CPR game is strategic complementary if and only if there exists sufficiently high degree of connection such that

$$k_i > \frac{b}{\delta(N-1)} - \frac{\delta}{2\nu(N-1)}(\bar{x}_{-i} - \tilde{x}_{-i})(\bar{x}_i - x_i). \tag{3.15}$$

On the other hand, if the above condition does not hold, then the CPR game is strategic substitute $\frac{\partial x}{\partial x_{-i}} < 0$. This means that all agents will suffer resource loss if one increase his or her extraction; Otherwise, if an agent reduces his or her extraction, then others would gain more resource by increasing their extraction. This is a nature of the CPR game because of the substractability property of the commons. Therefore, in the presence of network, a network with more connection would help to shift individual behavior from strategic substitute to complementarity if and only if the following condition is satisfied $k_i > \frac{b}{\delta(N-1)} - \frac{\delta}{2\nu(N-1)}(\bar{x}_{-i} - \tilde{x}_{-i})(\bar{x}_i - x_i)$.

Equilibrium

From the optimization problem 3.13, we have the following Lagrangian

$$
\begin{aligned}
\mathcal{L}(x_i, k_i) = {} & (a - bX)x_i - \gamma x_i^2 - \nu[(N-1)k_i]^2 + \delta k_i(N-1)(\bar{x} - \tilde{x}_{N_i(g)})(\bar{x} - x_i) \\
& - \lambda_1(x_i - \bar{x}) - \lambda_2(k_i - 1) + \lambda_3 x_i + \lambda_4 k_i,
\end{aligned} \tag{3.16}
$$

where, $\bar{x}_i = \bar{x}_j = \bar{x}_{N_i(g)} = \bar{x}$ and $\tilde{x}_{N_i(g)} = \frac{1}{|N_i(g)|}\sum_j^N g_{ij}x_j = \frac{1}{k_i(N-1)}\sum_j^N g_{ij}x_j$ since all agents are identical by assumption.

We have the F.O.C of the Lagrangian as follows:

$$
\begin{aligned}
\frac{\partial \mathcal{L}}{\partial x_i} &= a - b(X + x_i) - 2\gamma x_i - \delta k_i(N-1)(\bar{x} - \tilde{x}_{N_i(g)}) - \lambda_1 + \lambda_3 = 0 \\
\frac{\partial \mathcal{L}}{\partial k_i} &= -2\nu(N-1)^2 k_i + \delta(N-1)(\bar{x} - \tilde{x}_{N_i(g)})(\bar{x} - x_i) - \lambda_2 + \lambda_4 = 0
\end{aligned}
$$

Recall the KKT conditions, we can check whether all the conditions are satisfied.

Case 1. We have zero utility because $x_i = 0$, $k_i = 0$ and $B(0, x_{N_i(g)}, 0) = 0$. Thus, in this case, we have a corner solution $(\underline{x}^c; \underline{k}^c) = (0; 0)$.

Case 2. We have $x_i > 0$ and $k_i = 0$. Thus, $\lambda_3 = 0$ by the complementary slackness condition (3.6). Therefore, from the KKT condition, we have a corner solution

$$\underline{x}^c = \frac{a - \lambda_1}{b(N+1) + 2\gamma}, \quad \text{for } \lambda_1 \geq 0 \quad \text{and} \quad \underline{k}^c = 0$$

For $\lambda_1 > 0$, by the complementary slackness, we have $\bar{x}^c = \bar{x}$ and $\underline{k}^c = 0$ if $\lambda_1 = a - [b(N+1) + 2\gamma]\bar{x} > 0$. For $\lambda_1 = 0$, we need the constraint $x_i < \bar{x}$ by the complementary slackness (3.4). Thus, the solutions are $\underline{x}^c = \frac{a}{b(N+1)+2\gamma}$ and $\underline{k}^c = 0$.

Case 3. We have the constraint $x_i \geq 0$ is binding and $k_i \geq 0$ is not binding. Thus, from the complementary slackness, we need $\lambda_3 = 0$ and $\lambda_4 > 0$. The Lagrangian (3.16) is rewritten as follows.

$$\mathcal{L}(k_i) = -2\nu(N-1)^2 k_i + \delta B(0, x_{N_i(g)}, k_i) - \lambda_1(x_i - \bar{x}) - \lambda_2(k_i - 1)$$

where, $B(0, x_{N_i(g)}, k_i) = k_i(N-1)(\bar{x} - \tilde{x}_{N_i(g)})\bar{x}$.

Under the condition $U(0, k_i) \geq 0$ which is equivalent to $\nu(N-1)k_i^2 \leq \delta(\bar{x} - \tilde{x}_{N_i(g)})\bar{x}$, we have

$$\frac{\partial \mathcal{L}}{\partial k_i} = -2\nu(N-1)^2 k_i + \delta(N-1)(\bar{x} - \tilde{x}_{N_i(g)})\bar{x} - \lambda_2 = 0$$

At the equilibrium, we have $x_i = x_j = \underline{x}^c = 0$ and thus $\tilde{x}_{N_i(g)} = 0$. For $\lambda_2 > 0$, then by the complementary slackness, we have $\bar{k}^c = 1$ and $\lambda_2 = \delta\bar{x}^2 - 2\nu(N-1) > 0$. For $\lambda_2 = 0$, we have a corner solution $\underline{x}^c = 0$ and $\underline{k}^c = \frac{\delta\bar{x}^2}{2\nu(N-1)}$.

Case 4. We have both x_i and k_i are strictly positive and thus $\lambda_3 = \lambda_4 = 0$ by the slackness condition (3.6) and (3.7). Now, concerning the complementary slackness (3.4) and (3.5), we have also four following cases.

Case 4.a. We have the constraint $x_i \leq \bar{x}$ is not binding and $k_i \leq 1$ is binding. Thus, $\lambda_1 = 0$ and $\lambda_2 > 0$. We have the following Lagrangian.

$$\mathcal{L}(x_i, k_i) = (a - bX)x_i - \gamma x_i^2 - \nu[(N-1)k_i]^2 + \delta k_i(N-1)(\bar{x} - \tilde{x}_{N_i(g)})(\bar{x} - x_i) - \lambda_2(k_i - 1)$$

Taking the F.O.C with respect to x_i and k_i, we have

$$\frac{\partial \mathcal{L}}{\partial x_i} = a - b(X + x_i) - 2\gamma x_i - \delta k_i (N-1)(\bar{x} - \tilde{x}_{N_i(g)}) = 0$$
$$\frac{\partial \mathcal{L}}{\partial k_i} = -2\nu(N-1)^2 k_i + \delta(N-1)(\bar{x} - \tilde{x}_{N_i(g)})(\bar{x} - x_i) - \lambda_2 = 0$$

Since the $k_i \leq 1$ is binding, from the complementary slackness, we have $\bar{k}^c = 1$ at the equilibrium. Solving the above system equations, we obtain the solutions

$$\bar{x}^c = \frac{a - \delta(N-1)\bar{x}}{(N+1)b + 2\gamma - \delta(N-1)}, \quad \bar{k}^c = 1, \quad \text{and } \lambda_2 = -2\nu(N-1)^2 + \delta(N-1)(\bar{x} - \bar{x}^c)^2.$$

It should be noted that the case 4.a will not be satisfied if $\lambda_2 = -2\nu(N-1)^2 + \delta(N-1)(\bar{x} - \bar{x}^c)^2 < 0$.

Case 4.b. We have, in this case, $\lambda_1 > 0$ and $\lambda_2 = 0$. From the slackness condition, we have $x_i = \bar{x}$. Thus, at the equilibrium, we have $\bar{x}^c = \bar{x}$. Similarly, from the F.O.C, we obtain

$$a - b(N+1)\bar{x}^c - 2\gamma\bar{x}^c - \lambda_1 = 0$$
$$-2\nu(N-1)^2\bar{k}^c = 0$$

By solving these system equations, we have the corner solutions.

$$\bar{x}^c = \bar{x}, \quad \underline{k}^c = 0, \quad \text{and } \lambda_1 = a - [b(N+1) + 2\gamma]\bar{x}.$$

We also need $\lambda_1 = a - [b(N+1) + 2\gamma]\bar{x} > 0$ in order for the KKT condition to be satisfied.

Case 4.c. We have both constraints are binding. Thus, $x_i = \bar{x}$, $k_i = 1$, $\lambda_1 > 0$ and $\lambda_2 > 0$. We have, at the equilibrium,

$$\bar{x}^c = \bar{x} \quad \bar{k}^c = 1.$$

And we can find λ_1 and λ_2 by solving the F.O.C.

$$a - [(N+1)b + 2\gamma]\bar{x}^c = \lambda_1$$
$$-2\nu(N-1)^2\bar{k}^c = \lambda_2$$

We observe that $\lambda_2 = -2\nu(N-1)^2\bar{k}^c = -2\nu(N-1)^2 < 0$. Therefore, the KKT condition that $\lambda_2 > 0$ is violated.

Case 4.d. In this case, we have $\lambda_1 = \lambda_2 = 0$. Let x^* and k^* be the interior equilibrium solutions. From the KKT condition, we have

$$a - [(N+1)b + 2\gamma]x^* - \delta(N-1)k^*(\bar{x} - x^*) = 0 \tag{3.17}$$

$$-2\nu(N-1)^2 k^* + \delta(N-1)(\bar{x} - x^*)^2 = 0 \tag{3.18}$$

Thus, we have

$$\delta^2(\bar{x} - x^*)^3 + 2[(N+1)b + 2\gamma]\nu x^* - 2a\nu = 0 \tag{3.19}$$

We can solve this third order polynomial equations by using the Cardano method (see details in Appendix C). We obtain

$$x^* = \bar{x} - \frac{p^n}{3u^n} + u^n \tag{3.20}$$

$$k^* = \frac{\delta(\bar{x} - x^*)^2}{2\nu(N-1)} \tag{3.21}$$

where, $u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$ and $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x}-2a\nu}{\delta^2}$.

To sum up, there are totally seven corner solutions $(x^c; k^c)$ and three interior solutions $(x^*; k^*)$.

(i). Seven corner solutions:

- $(\underline{x}^c; \underline{k}^c) = (0; 0)$,
- $(\underline{x}^c; \underline{k}^c) = \left(0; \frac{\delta\bar{x}^2}{2\nu(N-1)}\right)$,
- $(\underline{x}^c; \underline{k}^c) = \left(\frac{a}{b(N+1)+2\gamma}; 0\right)$,
- $(\underline{x}^c; \bar{k}^c) = (0; 1)$, where $\lambda_2 = \delta(N-1)\bar{x}^2 - 2\nu(N-1)^2 > 0$,
- $(\bar{x}^c; \underline{k}^c) = (\bar{x}; 0)$, where $\lambda_1 = a - [b(N+1) + 2\gamma]\bar{x} > 0$,
- $(\bar{x}^c; \bar{k}^c) = \left(\frac{a-\delta(N-1)\bar{x}}{(N+1)b+2\gamma-\delta(N-1)}; 1\right)$, where $\lambda_2 = -2\nu(N-1)^2 + \delta(N-1)(\bar{x} - \bar{x}^c)^2 > 0$.

(ii). Three interior solutions: $(x^*, k^*) = \left(\bar{x} - \frac{p^n}{3u^n} + u^n; \frac{\delta}{2\nu}\left(\frac{p^n}{3u^n} - u^n\right)^2\right)$,
where, $u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$ and $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x}-2a\nu}{\delta^2}$.

Relationship between equilibrium extraction and network connection

From Equation (3.21), the impact of equilibrium extraction on the equilibrium network connection can be calculated as follows:

$$\frac{\partial k^*}{\partial x^*} = -\frac{\delta(\bar{x} - x^*)}{\nu(N-1)}.$$

We observe that $\frac{\partial k^*}{\partial x^*}$ is always negative because we always have $\bar{x} - x^* \geq 0$, $\frac{\partial k^*}{\partial x^*} \leq 0$.

Additionally, from Equation (3.20), we have the equilibrium extraction as a function of the equilibrium network connection as follows:

$$x^* = \frac{a - \delta(N-1)k^*\bar{x}}{(N+1)b + 2\gamma - \delta(N-1)k^*}.$$

Taking the derivative of this equation with respect to k^*, we have

$$\frac{\partial x^*}{\partial k^*} = \delta \frac{a - [(N+1)b + 2\gamma]\bar{x}}{[(N+1)b + 2\gamma - \delta(N-1)k^*]^2}.$$

We could observe that $\frac{\partial x^*}{\partial k^*} \leq 0$ if we have $a - [(N+1)b + 2\gamma]\bar{x} \leq 0$ or $\bar{x} \geq \frac{a}{(N+1)b+2\gamma}$.

Taken together, these results lead us to the following proposition.

Proposition 1. An agent who has higher effort in conserving the CPR is more likely to connect to more other agents and thus have higher network connection, $\frac{\partial k^*}{\partial x^*} < 0$ if there exists an effort capacity $\bar{x}$ such that $\bar{x} \geq \frac{a}{(N+1)b+2\gamma}$.

In the case of no connection between agents (i.e., empty network where there is no links between agents ($k^* = 0$)), we have a simple CPR game with $x^* = \frac{a}{(N+1)b+2\gamma}$. This result suggests that the over-exploitation of the common resource will not happen if we have a sufficiently high extraction cost, γ; Otherwise, all of the agents will have incentives to extract the resource with their maximum effort (i.e., $x^* = \bar{x}$).

In the presence of network ($k^* > 0$), our result in Proposition 1 suggests that there is a negative relationship between network connection and extraction effort, $\frac{\partial k^*}{\partial x^*} < 0$. This result can be easily interpreted because a link between agents can be established if and only if $\nu < \delta(\bar{x} - x_j)(\bar{x} - x_i)$ for any $j \in N_i(g)$. At the equilibrium, we have $\nu < \delta(\bar{x} - x^*)^2$ and thus an increasing equilibrium extraction x^* leads to a reduction in benefit gains from the network. Therefore, it makes the links between agents less likely to be initiated.

However, our results also indicate that there exists one equilibrium path $\frac{\partial x^*}{\partial k^*} \geq 0$ for $\bar{x} < \frac{a}{(N+1)b+2\gamma}$, meaning that the effort capacity is lower than the equilibrium extraction in the case of no connection. This means that agents compete in extracting the resource in a situation of *resource scarcity* since we have $\bar{X} = N\bar{x}$. Thus, encouraging the network connection in this case may not help to promote the resource conservation, but it could otherwise lead to more serious over-extraction of the common, $\frac{\partial x^*}{\partial k^*} \geq 0$.

Impact of linking cost

From Equation (3.21), we observe that

$$\frac{\partial k^*}{\partial \nu} = -\frac{\delta(\bar{x} - x^*)^2}{4\nu^2(N-1)} \leq 0.$$

By the chain rule, we have

$$\frac{\partial x^*}{\partial \nu} = \frac{\partial x^*}{\partial k^*}\frac{\partial k^*}{\partial \nu}.$$

Since we previously know that $\frac{\partial x^*}{\partial k^*} \leq 0$ if $\bar{x} \geq \frac{a}{(N+1)b+2\gamma}$, thus we would have

$$\frac{\partial x^*}{\partial \nu} \geq 0.$$

Therefore, these results lead us to the following proposition.

Proposition 2. A higher linking cost results in a lower network connection $\frac{\partial k^*}{\partial \nu} \leq 0$ and a higher equilibrium resource extraction $\frac{\partial x^*}{\partial \nu} \geq 0$ if $\bar{x} \geq \frac{a}{(N+1)b+2\gamma}$.

This result indicates that in order to encourage the resource conservation, we should ensure as low as possible linking cost to promote the network connection between agents. Since with a relatively low linking cost, agents have more incentive to form connections with others. When there are connections among agents, they would take into account themselves as well as their neighborhood conservation efforts. Thus, a low linking cost is needed to promote the CPR conservation. However, in order to ensure the existence of interior equilibrium solutions, we need also ensure a not two low linking cost as indicated in Lemma 1 ($\nu > \frac{(\delta\phi_i)^2}{4(b+\gamma)}$). It should be noted that when connection cost is too high, there will be an empty network (i.e., no link among agents) which is justified by the previous KKT conditions. In an empty network, we have a simple common pool resource game and the over-exploitation problem is likely to happen if there is a low extraction cost of the common resource.

Impact of social influence

By the same logic, from Equation (3.21), we have

$$\frac{\partial k^*}{\partial \delta} = \frac{(\bar{x} - x^*)^2}{2\nu(N-1)} \geq 0.$$

And, we would also have

$$\frac{\partial x^*}{\partial \delta} = \frac{\partial x^*}{\partial k^*}\frac{\partial k^*}{\partial \delta} \leq 0 \quad \text{if} \quad \bar{x} \geq \frac{a}{(N+1)b + 2\gamma}.$$

Therefore, these results lead us to the following proposition.

Proposition 3. A higher social influence parameter results in a higher network connection $\frac{\partial k^*}{\partial \delta} \geq 0$ and a lower equilibrium extraction $\frac{\partial x^*}{\partial \delta} \leq 0$ if there exists $\bar{x} \geq \frac{a}{(N+1)b+2\gamma}$.

The result of Proposition 3 is complementary with Proposition 2 because by assumption in order for a link between i and j to be established ($g_{ij} = 0$), we need $\nu \leq \delta(\bar{x} - x_j)(\bar{x} - x_i)$ for $j \in N_i(g)$. As a result, instead of promoting lower linking cost to encourage resource conservation, we could also promote higher social influence to motivate agents to initiate links with others and thus helps prevent the over-exploitation of the CPR. As previously mentioned, a more likely a link is formed, a higher possibility of promoting the CPR conservation since agents have to take themselves and their neighbors' behavior into account. Therefore, in addition to the linking cost, policymaker should also take the social influence into account in order to more effectively motivate individuals to conserve the common resources.

3.3 Welfare analysis

3.3.1 Socially optimal extraction and network connection

Let x^e and k^e be the socially optimal extraction and network connection, which maximizes the following aggregate payoff.

$$\max_{x_i,k_i} \sum_i U_i = \max_{x_i,k_i} \sum_i^N \{f(X)\frac{x_i}{X} - \gamma x_i^2 - \nu[(N-1)k_i]^2 + \delta \sum_{j \in N_i(g)} B(x_i, x_j, k_i)\} \tag{3.22}$$

where, the social influence $B(x_i, x_j, k_i) = k_i(N-1)(\bar{x} - \tilde{x}_{N_i(g)})(\bar{x} - x_i)$.

From the maximization problem 3.22, we have the F.O.C with respect to x_i and k_i as follows:

$$a - 2b\sum_i x_i - 2\gamma x_i - \delta k_i(N-1)(\bar{x} - \tilde{x}_{N_i(g)}) - \delta k_j(N-1)(\bar{x} - \tilde{x}_{N_j(g)}) = 0$$
$$-2\nu(N-1)^2 k_i + \delta(N-1)(\bar{x} - \tilde{x}_{N_i(g)})(\bar{x} - x_i) = 0.$$

At the social optimum, we have

$$a - 2Nbx^e - 2\gamma x^e - 2\delta(N-1)k^e(\bar{x} - x^e) = 0$$
$$-2\nu(N-1)^2 k^e + \delta(N-1)(\bar{x} - x^e)^2 = 0$$

Thus, we have $k^e = \frac{\delta(\bar{x}-x^e)^2}{2\nu(N-1)}$ and

$$a - 2(Nb+\gamma)x^e - 2\frac{\delta^2}{\nu}(\bar{x} - x^e)^3 = 0.$$

Solving this third order degree polynomial equation (see detailed proof in Appendix C), we obtain the socially optimal extraction and network connection as follows:

$$x^e = \bar{x} - \frac{p^e}{3u^e} + u^e \tag{3.23}$$
$$k^e = \frac{\delta(\bar{x} - x^e)^2}{2\nu(N-1)}, \tag{3.24}$$

where, $u^e = (\frac{q^e}{2} \pm \sqrt{\frac{q^{e2}}{4} + \frac{p^{e3}}{27}})^{\frac{1}{3}}$, $p^e = -\frac{2(Nb+\gamma)\nu}{\delta^2}$ and $q^e = \frac{2(Nb+\gamma)\nu\bar{x} - a\nu}{\delta^2}$.

3.3.2 Efficiency

From Equation (3.24), we obtain the socially optimal extraction x^e as a function of k^e.

$$x^e = \frac{2\bar{x} - \sqrt{\Delta^e}}{2},$$

where, $\Delta^e = \frac{8\nu}{\delta}\bar{x}^2 k^e$. It should be noted that the upper socially optimal $x^e = \frac{2\bar{x}+\sqrt{\Delta^e}}{2} > \bar{x}$ violates the condition that $x_i \leq \bar{x}$.

We observe that $x^e < x^*$ because $k^e > k^*$. Thus, we have $x^* = x^e$ if there exists a positive rent d such that $x^* - d = x^e$.

$$d = \frac{1}{2}(\sqrt{\Delta^e} - \sqrt{\Delta^*}),$$

where, $\Delta^e = \frac{8\nu}{\delta}\bar{x}^2 k^e$ and $\Delta^* = \frac{8\nu}{\delta}\bar{x}^2 k^*$.

This leads us to the following proposition.

Proposition 4. The outcome of Nash equilibrium x^* is efficient if there exists a positive rent d such that $x^* - d = x^e$, where $d = \frac{1}{2}(\sqrt{\Delta^e} - \sqrt{\Delta^*})$, $\Delta^e = \frac{8\nu}{\delta}\bar{x}^2 k^e$ and $\Delta^* = \frac{8\nu}{\delta}\bar{x}^2 k^*$.

This proposition suggests that the Nash equilibrium will be efficient if the positive rent d equals to zero. The only way to minimize d is to minimize the difference between k^e and k^*. We have $k^e - k^* = 0$ is equivalent to

$$\frac{p^e}{3u^e} - u^e - \frac{p^n}{3u^n} + u^n = 0.$$

where, $u^e = (\frac{q^e}{2} \pm \sqrt{\frac{q^{e2}}{4} + \frac{p^{e3}}{27}})^{\frac{1}{3}}$, $p^e = -\frac{2(Nb+\gamma)\nu}{\delta^2}$, $q^e = \frac{2(Nb+\gamma)\nu\bar{x} - a\nu}{\delta^2}$ and $u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$, $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x} - 2a\nu}{\delta^2}$.

We observe that we could let $\Delta^e = \Delta^* = 0$ to minimize d, but in this case, the CPR has only one solution with $x^e = x^* = \bar{x}$. Thus, there will exist the over-exploitation problem of the CPR.

In the case that $\Delta^* > 0$ and $\Delta^e > 0$, we can observe that

$$\begin{aligned} p^e - p^n &= -\frac{2(Nb+\gamma)\nu}{\delta^2} + \frac{[2(N+1)b+4\gamma]\nu}{\delta^2} \\ &= \frac{\nu}{\delta^2}[b + 2\gamma]. \end{aligned}$$

We observe that the difference between Nash equilibrium and social optimum can be minimized by firstly reducing b which will reduce the benefit gain from extracting the common resource because $f(X) = aX - bX^2$. Thus, agents would have lower incentive to extract more resource from the common pool. Secondly, we could encourage the resource conservation by reducing the linking cost ν (i.e., encourage the socialization) since one connects to his/her neighbors, would take the conservation effort of him/herself and his/her neighbors into account. Finally, promoting the social influence by increasing the social influence parameter δ, which can help to either promote the network connection or agents' conservation efforts. For instance, one who cares more about others may have lower incentive to over-extracting the common pool resource than those who do not.

3.4 Numerical analysis

In this section, we provide a numerical analysis of our analytical results. We consider that the resource capacity $\bar{X} = 5$ and there are totally 5 agents ($N = 5$) competing in a common pool resource game. Thus, we have each agent's effort capacity $\bar{x} = \frac{\bar{X}}{5} = 1$. However, each agent can decide to invest $x \in [0, \bar{X}]$ to extract the common resource, but if the total effort is equal or higher than the resource capacity, $X \geq \bar{X}$, then each agent would share a total payoff $f(\bar{X})$, such that $f(\bar{X})\frac{x_i}{x_i+x_{-i}}$.

Regarding the effort function, we consider that $f(X) = aX - bX^2$ with $a = 2$ and $b = 0.4$ in order to ensure that $f(X)$ is increasing (i.e., $f^{'}(X) \geq 0$) for any $X \leq \frac{1}{2} * 5 = 2.5$. From this assumption, we can observe that $f(X) = 0$ for $\bar{X} = 5$ (i.e., there are totally 5 agents ($N = 5$) and each agent invests $x = 1$), meaning that without any extraction cost or presence of social influence, no agent would have no incentive to put more than the maximum capacity of effort in harvesting the common good. In other words, $f(\bar{X})\frac{x_i}{x_i+x_{-i}}$ will not happen. The extraction cost of the CPR, γ, for each unit of extracted resource is assumed to be homogeneous across agents and be equal to 0.5. This means that it is costly for each agent to extract the resource, and thus there will be no over-exploitation in the situation of no network and social influence.

In the presence of network and social influence, we have to choose the linking cost ν such that $\nu \leq (\bar{x} - x_j)(\bar{x} - x_i)$. For instance, a link will be formed between agent i and j who put 60% of their efforts to extract the common resource (i.e., they conserve the resource by putting 40% of their efforts) if we have $\nu \leq 0.7 \times (1 - 0.6) \times (1 - 0.6) = 0.112$. Therefore, we set $\nu = 0.1$ with $\delta = 0.7$ and thus, agents who conserve the resource by extracting less than 60% of their efforts would have incentive to initiate links with others who also conserving the common good by extracting less than 60%. Therefore, we have

$$a = 2, \quad b = 0.4, \quad N = 5, \quad \gamma = 0.5, \quad \nu = 0.1 \quad \delta = 0.7, \quad \bar{X} = 5.$$

The optimization is following the maximization (3.13) and agent i will choose x_i and k_i to maximize their payoffs. Thus, we have the following interior equilibrium solutions.

$$x^* = \bar{x} - \frac{p^n}{3u^n} + u^n \tag{3.25}$$

$$k^* = \frac{\delta}{2\nu}\left(\frac{p^n}{3u^n} - u^n\right)^2 \tag{3.26}$$

where, $u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$ and $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x}-2a\nu}{\delta^2}$.

From these assumptions, there exists three equilibrium solutions $(x_1^*, k_1^*) = (0.157, 0.620)$, $(x_2^*, k_2^*) = (0.495, 0.222)$ and $(x_3^*, k_3^*) = (2.346, 1.000)$. The first equilibrium suggests that there are totally 5 agents and each agent invest nearly 15% of his or her effort in extracting the common resource with the optimal network connection equal to 62%. This suggests that it is optimal for every agent to connect to 62% of total number of agents in the group. However, equilibrium x_1 and x_3 are locally unstable. The stable equilibrium x_2 is that each agent should invest 49.5% of his or her effort and connect to 22.2% of the total potential connections. This equilibrium is locally stable, meaning that it is possible to achieve a sustainable resource extraction by promoting social influence in network (the detailed discussion about the stability will be discussed in next Section).

3.4.1 Best response functions

For simplicity, let's consider that there are two agents i and j extracting/harvesting a common good, meaning that $N = 2$. Since the network is indirect, these two agents i and j can decide whether to link to each other (i.e., $g_{ij} = 1$ and $k_i = k_j = 1$) or not (i.e., $g_{ij} = 0$ and $k_i = k_j = 0$). Let $B_i(x_j)$ and $B_j(x_i)$ be the best response function of i and j, respectively. From F.O.C (3.9) and (3.10), we have the agent i's best response function as follows:

$$B_i(x_j) = \frac{a - bx_j - \delta k_i(\bar{x}_j - x_j)}{2(b+\gamma)}.$$

By symmetry, we have

$$B_j(x_i) = \frac{a - bx_i - \delta k_j(\bar{x}_i - x_i)}{2(b+\gamma)}.$$

Since we only have two agents, they must either link with each other or not (i.e., $g_{ij} = 1$ or $g_{ij} = 0$). Then, we should have two following cases:
Case 1: $g_{ij} = 0$**.**

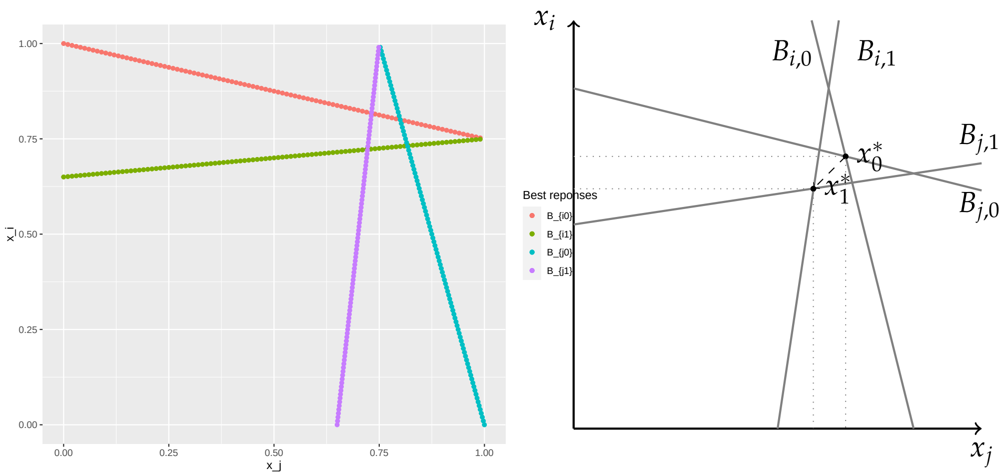
$$B_{i,0}(x_j) = \frac{a - bx_j}{2(b+\gamma)}.$$

$$\text{By symmetry,} \quad B_{j,0}(x_i) = \frac{a - bx_i}{2(b+\gamma)}.$$

In this case, we have a simple common pool game which has been widely investigated in the literature. From the best response function, it is obvious that we have a strategic substitute since $\frac{\partial B_i}{\partial x_j} < 0$ and $\frac{\partial B_j}{\partial x_i} < 0$. This suggests that others will extract more resource if one reduces the extraction and thus no agent has incentive to conserve the resource by reducing his or her extraction effort. This is in line with the existing literature of the CPR game (Roy and Sabarwal, 2012).
Case 2: $g_{ij} = 1$**.**
If they link to each other, we have $g_{ij} = g_{ji} = 1$ since the network is indirect. From the

previous best response functions, we have

$$B_{i,1}(x_j) = \frac{a - bx_j - \delta(\bar{x}_j - x_j)}{2(b+\gamma)}.$$
$$B_{j,1}(x_i) = \frac{a - bx_i - \delta(\bar{x}_i - x_i)}{2(b+\gamma)}.$$



(a) Simulation results. **(b)** Theoretical illustration.

Figure 3.1: The best response functions when $g_{ij} = 0$ and $g_{ij} = 1$.

Figure 3.1 illustrates the best response B_i and B_j with our parameter assumption. It suggests that the best response strategies are strategic substitute, $\frac{\partial x_i}{\partial x_j} < 0$ in the case that $g_{ij} = 0$. However, in the case of $g_{ij} = 1$, the best response functions $B_{i,1}(x_j)$ and $B_{j,1}(x_i)$ suggest that there exist a strategic complementarity between x_i and x_j. This means that the social influence through network could play a role in shifting individual from strategic substitute to strategic complementarity. In this way, motivating a resource conservation of one agent in the network could possibly help to promote the conservation behaviors of his or her direct neighbors. Therefore, the social influence through network makes the cooperation in conserving the common resource more likely to sustain than the case of without network.

3.4.2 The relationship between the equilibrium network connection and the equilibrium extraction effort of the CPR

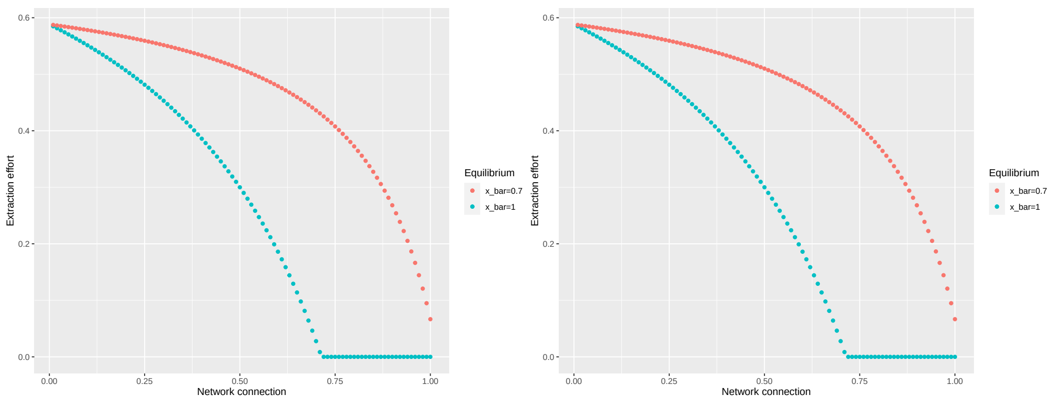
In order to study the relationship between the equilibrium network connection and the equilibrium extraction effort, we can also express the equilibrium extraction x^* as a function of network connection k and the equilibrium network connection as a function of x as follows:

$$x^* = \frac{a - \delta(N-1)k\bar{x}}{(N+1)b + 2\gamma - \delta(N-1)k}. \tag{3.27}$$

$$k^* = \frac{\delta(\bar{x} - x)^2}{2\nu(N-1)}. \tag{3.28}$$

From Figure 3.1(a), we have two equilibrium extractions corresponding to two different equilibrium network connections k ($k = 0$ and $k = 1$ since there are only two agents). We observe that the equilibrium changes when the network connection k varies. Let x_0^* and x_1^* be the equilibrium at $k = 0$ and $k = 1$, respectively. We illustrate these equilibrium solutions in Figure 3.1(b). Figure 3.1(b) shows a negative relationship between the network connection and the extraction of the CPR because the equilibrium x_0^* move from a higher equilibrium to a lower equilibrium $x_1^* < x_0^*$ as k goes from 0 to 1. This result validates partially our Proposition 1 which suggests that network connection could help to incentivize agents to conserve the common resource.

In the previous example, we discuss the relationship between network connection and resource extraction when there are only two agents. In a general case, when there exists N agents ($N = 5$ by assumption), each agent could possibly form links with $N - 1$ other agents (i.e., potential connections). In this case, we also observe that there is a negative relationship between network connection (i.e., the fraction of direct links/connections) and the resource extraction (Figure 3.2). This is in line with our theoretical findings in Proposition 1.



(a) Network connection. **(b)** Extraction effort.

Figure 3.2: Equilibrium extraction effort and network connection with different $\bar{x}$.

When we reduce the effort capacity from $\bar{x} = 1$ to $\bar{x} = 0.7$, we also observe the negative relationship between network connection and resource extraction. In this case, we have one locally stable equilibrium solution which is $(x^*, k^*) = (0.587, 0.011)$. This means that in the situation of resource scarcity ($\bar{x} = 0.7$), social influence through network could play an important role in incentivizing the resource conservation. However, it is necessary to keep a sufficient low cost of linking in order to incentivize the network connection since we have a very low $k^* = 0.019$. In this case, if we sightly increase the cost of linking, then it is obvious that the equilibrium of the CPR game will change from the locally stable interior equilibrium to the corner equilibrium $(x^*, k^*) = (0.625, 0)$ with no connection between individuals $k^* = 0$. In this case, we have a simple CPR game with no network and social influence. Thus, by simply relax the assumption of the extraction cost, the over-extraction of the CPR is likely to happen since all agents will have incentives to choose x^* ($x^* = 0.909$) which is closed to $\bar{x}$.

3.4.3 Local bifurcation

In order to study the impact of linking cost ν and social influence δ on the equilibrium extraction and network connection, we apply the theory of local bifurcation which can help to analyze how the local stability properties of equilibria changes as the parameter varies (Crawford, 1991).

From the system equation (3.17), the equilibrium extraction is a solution of the following equation.

$$-\delta^2(\bar{x} - x^*)^3 - 2[(N+1)b + 2\gamma]\nu x^* + 2a\nu = 0$$

Let $g(x)$ be a function such that

$$g(x) \equiv -\delta^2(\bar{x} - x)^3 - 2[(N+1)b + 2\gamma]\nu x + 2a\nu \tag{3.29}$$

The solution of $g(x) = 0$ gives us the equilibrium extraction effort as previously discussed. Let us recall the three equilibrium extractions.

$$x^* = \bar{x} - \frac{p^n}{3u^n} + u^n$$

where, $u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$ and $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x}-2a\nu}{\delta^2}$.
From these equilibrium extractions, we are able to calculate the equilibrium network connection as follows:

$$k^* = \frac{\delta(\bar{x} - x^*)^2}{2\nu(N-1)}. \tag{3.30}$$

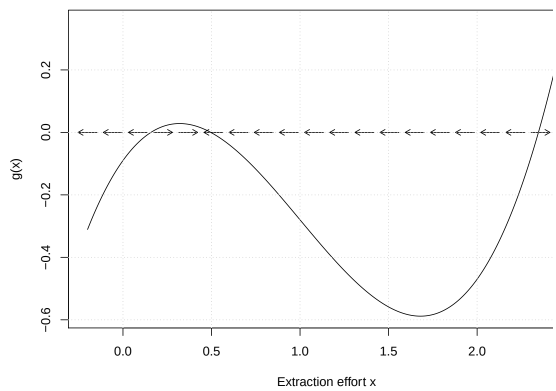
In order to draw a phase diagram for $g(x)$, we linearize Equation (3.29) around its steady state x^*. By linearlizing $g(x)$ near x^*, we have

$$\begin{aligned} L(x) &= g(x^*) + g_x(x^*)(x - x^*) \\ &= \left[3\delta^2(\bar{x} - x^*)^2 - 2((N+1)b + 2\gamma)\nu\right](x - x^*) \end{aligned}$$

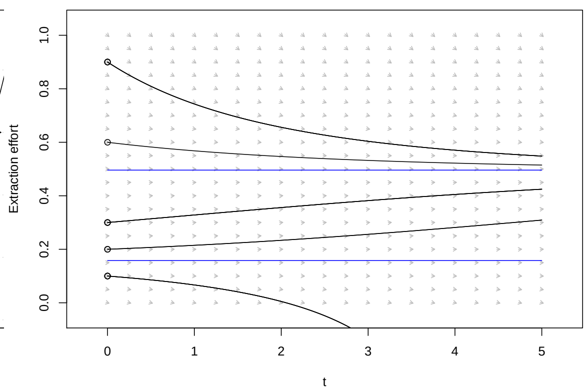
where, $g(x^*) = 0$. Then, from the different equation $\frac{dx}{dt} = L(x)$, we have

$$x(t) = x^* + \{x(0) - x^*\}\exp^{\left[3\delta^2(\bar{x}-x^*)^2 - 2((N+1)b+2\gamma)\nu\right]t}. \quad (3.31)$$

From this equation, we can draw the direction field and several trajectories as well as the phase portrait diagram for $g(x)$ in Figure 3.3. Let us denote the three set of equilibrium (x_1^*, k_1^*), (x_2^*, k_2^*) and (x_3^*, k_3^*) such that $x_1^* < x_2^* < x_3^*$ (Figure 3.3(a)). Figure 3.3(a) shows graphically that the equilibria x_1^* and x_3^* are unstable (which are also known as "source") but x_2^* is stable (i.e., a "sink").



(a) The phase portrait diagram for $g(x)$.



(b) The direction field and trajectories for $g(x)$.

Figure 3.3: Phase diagram and trajectories for $g(x)$.

The blue line in Figure 3.3(b) is represented for the equilibrium which is x_1^* and x_2^*. Thus, given any $x(0)$ start below or above the equilibrium x_2^*, for t grows from $0 \to \infty$, we will eventually converge to the stable equilibrium x_2^*. From our parameter assumptions, we are able to calculate that equilibrium solution $(x_2^*, k_2^*) = (0.495, 0.222)$. The two dimensional direction field and trajectories of x_2^* and k_2^* is presented in Figure 3.4. The two other unstable equilibrium x_1^* and x_3^* also exist in our model, presenting for the situation of under-extraction and over-exploitation of the CPR. The two dimensional plot with all three equilibrium is reported in Figure D.1 in Appendix D.

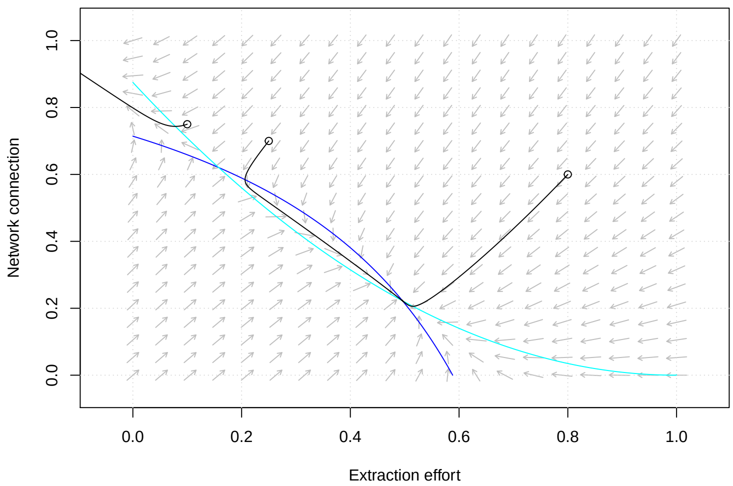


Figure 3.4: Two dimensional direction field and trajectories for extraction effort x against network connection k with (x_1^*, k_1^*) and (x_2^*, k_2^*).

Theoretically, from Equation (3.31), we observe that when the term $3\delta^2(\bar{x} - x^*)^2 - 2((N+1)b + 2\gamma)\nu < 0$, we would have $|x(t)| \to x^*$ as $t \to \infty$ for x^* which is locally stable. Otherwise, if $3\delta^2(\bar{x} - x^*)^2 - 2((N+1)b + 2\gamma)\nu > 0$, then we will have $|x(t)| \to \infty$ as $t \to \infty$ and the equilibrium x^* is locally unstable. Therefore, we have at

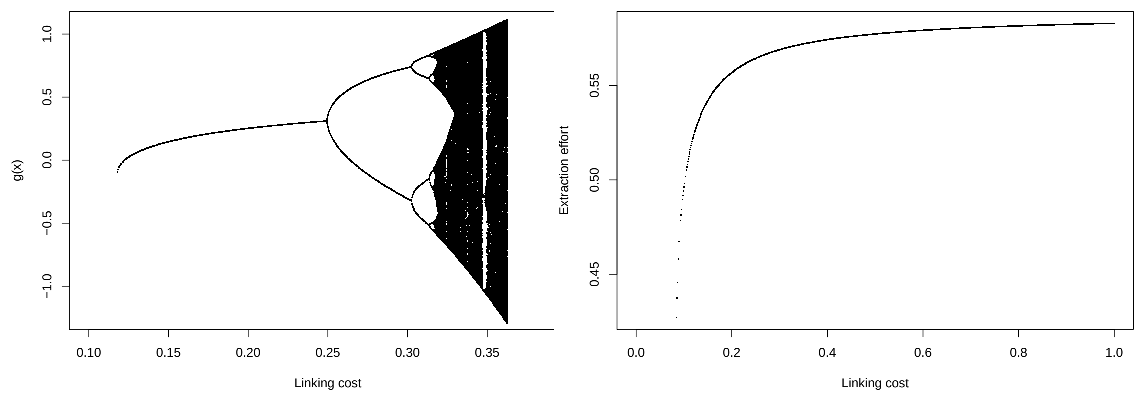
$$x^* = \bar{x} - \sqrt{\frac{2((N+1)b + 2\gamma)\nu}{3\delta^2}}.$$

corresponds to the creation of new solution branches. One of these is unstable (x_1^* or x_3^*), the other is stable (x_2^*). We can also observe that $x_2^* > \bar{x} - \sqrt{\frac{2((N+1)b+2\gamma)\nu}{3\delta^2}} = 0.519$ (the equilibrium $x_2^* = 0.495$). Therefore, we can conclude that the Nash equilibrium x_2^* in our model is locally stable. This means that the social influence through network could help to encourage individuals' long-term resource conservation behaviors. The equilibrium x_3^* is also satisfied the assumption $x_3^* > \bar{x} - \sqrt{\frac{2((N+1)b+2\gamma)\nu}{3\delta^2}}$ but $x_3^* > \bar{x}$, and thus it is not locally stable.

From function $g(x)$ in Equation (3.29), we observe that the number of equilibria changes from three to one depending on the values of p^n, q^n and u^n. In particular, when $p^n = q^n = 0$ and thus $u^n = 0$, we will have one solution $x^* = \bar{x}$. When $q^n = 0$, the equilibrium solution exists if and only if we have $u^n \neq 0$. If $p^n \neq 0$ and $q^n \neq 0$, we would have three equilibrium solutions. This is a form of bifurcation. We use the bifurcation diagram as a tool to illustrate how the number of equilibria and their classifications (sink, source or node) change with different model parameters. The values of p^n, q^n and u^n depend on several parameters but we choose the linking cost parameter ν and social influence parameter δ which are the key parameters of the social influence through network to illustrate these bifurcations.

Impact of linking cost

From Equations (3.29), we can draw the bifurcation diagram of the function $g(x)$ and the extraction effort x for different value of ν which is given in Figure 3.5. Figure 3.5(a) shows a bifurcation diagram of $g(x)$ depending on a parameter ν (i.e., a one dimensional map). The objective of a bifurcation diagram is to show the stable structures (fixed point, cycles, attractors) visited by the dynamics for each value of the so called "bifurcation parameter".



(a) Bifurcation of $g(x)$. **(b)** Bifurcation of x.

Figure 3.5: Bifurcation diagram of $g(x)$ and extraction effort x with different ν.

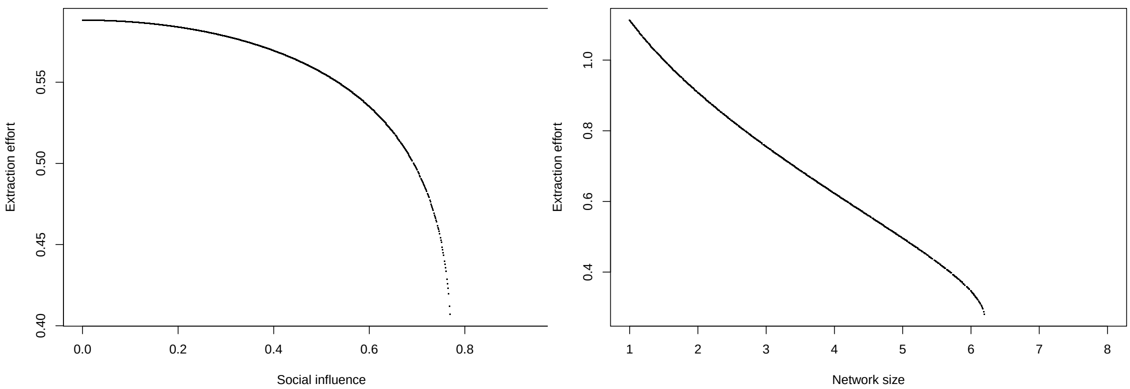
Figure 3.5(a) suggests that as the linking cost ν increases, we can observe the increasing in stable equilibrium extraction. This result is in line with our findings in Proposition 2. This result is also straightforward because higher linking cost leads to a more costly for agents to initiate links with others and thus results in a reduction in network connection. And, as a result, we will have a higher extraction of the CPR as the linking cost increases.

When parameter ν is relatively low ($\nu < 0.25$), we observe that there exists only one unique fixed point (i.e., a simple cycle). For $\nu > 0.25$, the dynamic system goes through a series of period-doubling bifurcations and chaos appears. When the linking cost crosses the value of 0.35, chaos suddenly disappears. This suggests that for any $\nu > 0.35$, it is too costly for agents to initiate links with others and thus no stable equilibrium exists. For any $\nu > 0.25$ and $\nu < 0.35$, the CPR game enters in the chaos and the over-exploitation and under-extraction of the CPR is highly likely to occur. Figure 3.5(b) supports this result by showing that for any $\nu > 0.4$, CPR game have no interior equilibrium solution and the stable equilibrium is the equilibrium of the CPR game in the case of empty network (i.e., no connection between agents). Therefore, ensuring a sufficiently low linking cost is essential to promote the network connection and sustain agents' behaviors in conserving the common pool resource.

Impact of social influence and network size

Similar to previous discussion of the impact of linking cost, in this section, we investigate about how the equilibrium solutions x^* changes as the social influence parameter δ and the network size vary (Figure 3.6). From Figures 3.6(a) and 3.6(b), we observe that as the parameter changes, there do not exist any series of period-doubling bifurcations or chaos in the equilibrium extraction.

In Figure 3.6(a), we observe that as social influence parameter increases, agents would have higher incentive to conserve the CPR and to initiate links with other agents. This result is in line with our Proposition 3. The interpretation is higher value of δ means higher benefit gained if agents conserve a common resource and thus agents have higher incentive to reduce their extraction of the CPR, as well as they are more likely to initiate links with others. However, the CPR game has only unique fixed point or stable equilibrium as $\delta < 0.8$. For any $\delta > 0.8$, there will be no stable equilibrium and thus the CPR game will reach either over-exploitation or under-extraction. Therefore, in order to avoid this catastrophic outcome, we have to keep $\delta < 0.8$.



(a) Social influence δ. **(b)** Network size N ($\bar{x} = 1$).

Figure 3.6: Bifurcation diagram of x with different δ and N.

Figure 3.6(b) suggests that we also have a simple cycle bifurcation diagram of equilibrium extraction as the bifurcation parameter N varies. Similar to the situation of social influence, increasing network size would also lead to reduce in resource extraction in the CPR game. It should be noted that in this bifurcation diagram, we give each agent a maximum effort capacity $\bar{x} = 1$, regardless of the network size. For $N = 1$ meaning that there is only one agent harvesting the resource, we will witness the over-exploitation of common resource because we observe that $x^* = \bar{x}$. However, the bifurcation disappears when $N > 6$, meaning that the game has more than 6 agents. This suggests that the CPR game will become locally unstable if we have more than 6 agents. This result is in line with the existing literature that the system of a CPR is locally unstable when there are more than four agents (Saijo et al., 2017).

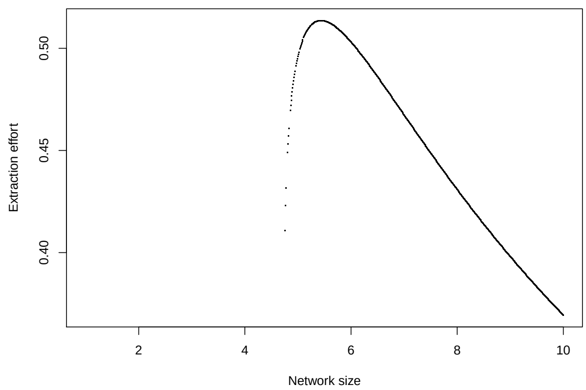


Figure 3.7: Bifurcation diagram of x with different N and given $\bar{X}$.

Moreover, instead of giving a homogeneous amount of effort capacity to all agents, we could give them the resource capacity $\bar{X}$. In this case, when there is only one agent, he or she can consume all the resource. As the network size increases, we will have higher competition because there are more and more agents competing to extract the resource. From Figure 3.7, when $N < 5$, we observe that there is no stable equilibrium. As the value of N increases, the resource extraction rapidly decreases. This is not because there is a present of network and social influence, but it also because there are more agents sharing the amount of resource $\bar{X}$. Therefore, it is also important to avoid either too few or too many agents competing in a CPR game. A sufficient network size is essential to sustain individuals' cooperative behavior in conserving the common resource.

3.5 Conclusion and discussion

Several studies have shown that humans may act collectively even in the social dilemma system (i.e., if one put effort to conserve the resource, others would take this opportunity to extract more resource. As argued by Ostrom (1990), humans have a natural attitude of cooperation and thus they do not act a priori as single players. Players would form coalitions and play the game according to their optimistic forecast.

In our study, we formulated this idea and applied it to the network-based common pool resource game. We assume that agents take into account their neighborhood resource conservation efforts when making their extraction decisions. They choose their optimal level of effort by comparing themselves with their direct neighbors (other agents in their networks), which is known as “social influence". We find that social influence through network can be used to shift individual behavior in harvesting the common resource from strategic substitute to strategic complementary strategy if there is a sufficiently low cost of linking (i.e., less costly for agents to form a link with others). And if the best response is strategic complementary then incentivizing one agent in conserving the common resource would possibly lead to a reduction in extraction of other agents in his or her network (i.e., his or her direct neighbors).

Moreover, our result suggests that there is a negative relationship between network connection and the extraction of the common goods. This is in line with the existing literature that socialization encourages people to care more about their personal images or what their neighbors think about their behaviors and thus they will be more likely to be influenced by other behaviors (Thaler, 2008). Thus, a sufficiently low cost of linking is essential to help to promote the network connection as well as incentivize the common resource conservation. In addition to the cost of linking, higher social influence could also provide agents higher incentives to form connections or links with others. Therefore, it is important to take either social influence or cost of linking into account since they are essential to encourage agents to behave toward resource conservation.

Network size is also important aspect which deserves deep investigation. Our model suggests that the system of a CPR game is not always locally stable as the network size varies. Depending on the maximum capacity of effort that each agent can invest in harvesting the common resource, a presence of too few or two many agents would give rise to the over-exploitation of the CPR (i.e., all agents put all their efforts to extract the resource) (Saijo et al., 2017). In particular, we find that the CPR game will become locally unstable if there are more than six agents competing in harvesting a common resource. Therefore, we suggest that policymaker or future research should carefully take the network size into account before designing a program which uses social influence through network to encourage individuals to conserve the common resource.

This analysis has several shortcomings which could be addressed by future research. Firstly, in this study, we consider the simultaneous move game (i.e., agents maximize their utility by simultaneously choosing the extraction effort and network connection). Thus, a sequential game, in which agents play a two stage game: a common pool game in the first step and then update the network link in the second step, could be also interesting (König et al., 2010). Our results in Appendix E suggest that solutions in the case of sequential game are similar to the case of simultaneous game. Secondly, since this is the static Nash equilibrium model, the agents did not take their own previous actions into account and thus this makes the model become less realistic. However, this kind of one-shot Nash equilibrium has been studies a lot in the public good game and thus it is simple but it is still very interesting to apply. In fact, in some situations, agents make decision regardless to their own previous behaviors, for example, agents who make their first decisions whether they should contribute to public good or not. But, the evolutionary game theoretical model or the dynamic social learning model is also a good approach that could be use to study the dynamic version of this common pool resources game (Szabó and Fath, 2007). Thirdly, we suggest that instead of using Nash equilibrium, we could study this model using the Lindahl equilibrium because in fact, at the equilibrium, each agent shares the same share of the common good but some agents may value the common good differently than others (Franke and Leininger, 2018; Foley, 1970; Lindahl, 1958). However, one of the limitation of the Lindalh equilibrium pricing is we do not exactly how much each agent values the certain good. But, it is important that the future research could take this issue into consideration. Finally, a high or low social influence through network depends on how strong the social norm in the agent's network. However, it is important to note that emergence of social norm is out of scope of this study. But, it is worth to be deeply investigated in future study because the social influence parameter depends on social norms and thus determines whether is is beneficial or not for an agent to initiate a link with his or her target neighbor.

Bibliography

Bandura, A. and F. J. Jourden (1991). Self-regulatory mechanisms governing the impact of social comparison on complex decision making. *Journal of Personality and Social Psychology 60*(6), 941.

Barnes-Mauthe, M., S. Arita, S. Allen, S. Gray, and P. Leung (2013). The influence of ethnic diversity on social network structure in a common-pool resource system: Implications for collaborative management. *Ecology and Society 18*(1), 23.

Bowles, S. and H. Gintis (2011). *A Cooperative Species: Human Reciprocity and its Evolution*. Princeton University Press.

Bramoullé, Y. and R. Kranton (2007). Public goods in networks. *Journal of Economic Theory 135*(1), 478–494.

Bramoullé, Y., R. Kranton, and M. D'amours (2014). Strategic interaction and networks. *American Economic Review 104*(3), 898–930.

Broecker, W. S. (1975). Climatic change: Are we on the brink of a pronounced global warming? *Science 189*(4201), 460–463.

Bromley, D. W. and M. M. Cernea (1989). *The Management of Common Property Natural Resources: Some Conceptual and Operational Fallacies*. World Bank Publications.

Cárdenas, J. C., C. Mantilla, and R. Sethi (2015). Stable sampling equilibrium in common pool resource games. *Games 6*(3), 299–317.

Chaudhuri, A. (2011). Sustaining cooperation in laboratory public goods experiments: A selective survey of the literature. *Experimental Economics 14*(1), 47–83.

Chiang, A. C. (1984). *Fundamental Methods of Mathematical Economics*. McGraw-Hill, Inc.

Crawford, J. D. (1991). Introduction to bifurcation theory. *Reviews of Modern Physics 63*(4), 991–1037.

De Geest, L. R., J. K. Stranlund, and J. M. Spraggon (2017). Deterring poaching of a common pool resource. *Journal of Economic Behavior & Organization 141*, 254–276.

Fischbacher, U. and S. Gachter (2010). Social preferences, beliefs, and the dynamics of free riding in public goods experiments. *American economic review 100*(1), 541–56.

Foley, D. (1970). Lindahl's solution and the core of an economy with public goods. *Econometrica 38*(1), 66–72.

Franke, J. and W. Leininger (2018). Lotteries and Lindahl prices in public good provision. *Journal of Public Economic Theory 20*(6), 840–848.

Frey, B. S. and S. Meier (2004). Social comparisons and pro-social behavior: Testing "conditional cooperation" in a field experiment. *American Economic Review 94*(5), 1717–1722.

Galeotti, A., S. Goyal, M. O. Jackson, F. Vega-Redondo, and L. Yariv (2010). Network games. *The Review of Economic Studies 77*(1), 218–244.

Gelcich, S., T. P. Hughes, P. Olsson, C. Folke, O. Defeo, M. Fernández, S. Foale, L. H. Gunderson, C. Rodríguez-Sickert, M. Scheffer, et al. (2010). Navigating transformations in governance of Chilean marine coastal resources. *Proceedings of the National Academy of Sciences 107*(39), 16794–16799.

Gould, R. V. (1993). Collective action and network structure. *American Sociological Review 58*, 182–196.

Hansen, J. E. and M. Sato (2001). Trends of measured climate forcing agents. *Proceedings of the National Academy of Sciences 98*(26), 14778–14783.

Hardin, G. (1968). The tragedy of the commons. *Science 162*(3859), 1243–1248.

Hinrichsen, D. (2016). *Our Common Seas: Coasts in Crisis*. Routledge.

Holländer, H. (1990). A social exchange approach to voluntary cooperation. *The American Economic Review 80*(5), 1157–1167.

König, M. D., C. J. Tessone, and Y. Zenou (2010). From assortative to dissortative networks: The role of capacity constraints. *Advances in Complex Systems 13*(04), 483–499.

Lindahl, E. (1958). Just taxation-a positive solution. In *Classics in the Theory of Public Finance*, pp. 168–176. Springer.

Mantilla, C. (2015). Communication networks in common-pool resource games: Field experimental evidence. *Journal of Economic Behavior & Organization 118*, 215–226.

Masuda, Y. J., Y. Liu, S. M. Reddy, K. A. Frank, K. Burford, J. R. Fisher, and J. Montambault (2018). Innovation diffusion within large environmental NGOs through informal network agents. *Nature Sustainability 1*(4), 190.

Ostrom, E. (1990). *Governing the Commons: The Evolution of Institutions for Collective Action*. Political Economy of Institutions and Decisions. Cambridge University Press.

Ostrom, E. (2008). The challenge of common-pool resources. *Environment: Science and Policy for Sustainable Development 50*(4), 8–21.

Ostrom, E., R. Gardner, and J. Walker (1994). *Rules, Games, and Gommon-Pool Resources*. University of Michigan Press.

Payne, N. L. and J. A. Smith (2017). An alternative explanation for global trends in thermal tolerance. *Ecology Letters 20*(1), 70–77.

Pearce, D. W. and R. K. Turner (1990). *Economics of Natural Resources and the Environment*. Johns Hopkins University Press.

Rege, M. and K. Telle (2004). The impact of social approval and framing on cooperation in public good situations. *Journal of Public Economics 88*(7-8), 1625–1644.

Roy, S. and T. Sabarwal (2012). Characterizing stability properties in games with strategic substitutes. *Games and Economic Behavior 75*(1), 337–353.

Saijo, T., J. Feng, and Y. Kobayashi (2017). Common-pool resources are intrinsically unstable. *International Journal of the Commons 11*(2), 597–620.

Schweitzer, F., G. Fagiolo, D. Sornette, F. Vega-Redondo, A. Vespignani, and D. R. White (2009). Economic networks: The new challenges. *Science 325*(5939), 422–425.

Sethi, R. and E. Somanathan (1996). The evolution of social norms in common property resource use. *American Economic Review 86*(4), 766–788.

Szabó, G. and G. Fath (2007). Evolutionary games on graphs. *Physics Reports 446*(4-6), 97–216.

Tavoni, A., M. Schlüter, and S. Levin (2012). The survival of the conformist: social pressure and renewable resource management. *Journal of Theoretical Biology 299*, 152–161.

Thaler, R. H. (2008). *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Walker, J. M., R. Gardner, and E. Ostrom (1990). Rent dissipation in a limited-access common-pool resource: Experimental evidence. *Journal of Environmental Economics and Management 19*(3), 203–211.

Appendix A: Sufficient condition for optimality.

Let us recall that the condition $H_2 > 0$ if we have

$$\frac{\partial^2 U}{\partial k^{*2}} < 0 \quad \text{and} \quad \frac{\partial^2 U}{\partial x^{*2}}\frac{\partial^2 U}{\partial k^{*2}} > \left(\frac{\partial^2 U}{\partial x^* \partial k^*}\right)^2.$$

Then, we have

$$\frac{\partial^2 U}{\partial k^{*2}} = -2\nu(N-1)^2 < 0.$$

Since $H_1 < 0$, we also have that

$$\frac{\partial^2 U}{\partial x^{*2}} = 2\delta(N-1)k^* - b(N+1) - 2\gamma < 0 \;\text{ and }\; \frac{\partial^2 U}{\partial x^* \partial k^*} = -2\delta(N-1)(\bar{x} - x^*).$$

Therefore, we have the sufficient condition for optimality (i.e., there exists a local maxima) as follows:

$$\begin{aligned} & \frac{\partial^2 U}{\partial x^{*2}}\frac{\partial^2 U}{\partial k^{*2}} > \left(\frac{\partial^2 U}{\partial x^* \partial k^*}\right)^2 \\ \Leftrightarrow \quad & \delta(\bar{x} - x^*)^2 + \nu(N-1)k^* < \frac{\nu}{2\delta}[b(N+1) + 2\gamma]. \end{aligned}$$

From the F.O.C., we have $\delta(\bar{x} - x^*)^2 = 2\nu(N-1)k^*$. Thus, we therefore have

$$k^* < \frac{1}{6\delta}[b(N+1) + 2\gamma].$$

Appendix B: The slope of the best response function.

Let us recall the system equations

$$\begin{aligned} U_{xx}\frac{\partial x_i}{\partial x_{-i}} + U_{xk}\frac{\partial k_i}{\partial x_{-i}} + U_{xx_{-i}} = 0 \\ U_{kx}\frac{\partial x_i}{\partial x_{-i}} + U_{kk}\frac{\partial k_i}{\partial x_{-i}} + U_{kx_{-i}} = 0 \end{aligned}$$

From the second equation, we could have

$$\frac{\partial k_i}{\partial x_{-i}} = -\frac{1}{U_{kk}}(U_{kx}\frac{\partial x}{\partial x_{-i}} + U_{kx_{-i}}).$$

Substituting this into the first equation, we have

$$\frac{\partial x_i}{\partial x_{-i}} = \frac{1}{U_{xx}U_{kk} - U_{xk}U_{kx}}[U_{xk}U_{kx_{-i}} - U_{xx_{-i}}U_{kk}].$$

Appendix C: Nash and socially optimal equilibrium solutions

Nash equilibrium

Recall the equation

$$\delta^2(\bar{x} - x^*)^3 + 2[(N+1)b + 2\gamma]\nu x^* - 2a\nu = 0$$

Let $y = \bar{x} - x^*$ and rearranging this equation, we have

$$y^3 - \frac{[2(N+1)b + 4\gamma]\nu}{\delta^2}y + \frac{[2(N+1)b + 4\gamma]\nu\bar{x} - 2a\nu}{\delta^2} = 0$$

Following the Cardano method, we let u^n, w^n such that

$$u^{n3} - w^{n3} = q^n \text{ and } u^n w^n = \frac{p^n}{3}$$

where, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$ and $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x}-2a\nu}{\delta^2}$.
Let $y = w^n - u^n$. Then, we have

$$(w^n - u^n)^3 + 3u^n w^n(w^n - u^n) + (u^{n3} - w^{n3}) = 0 \tag{3.32}$$

Since $u^n w^n = \frac{p^n}{3}$, then $w^n = \frac{p^n}{3u^n}$ and $u^{n3} - \frac{p^{n3}}{27u^{n3}} = q^n$. By substituting u^n, w^n into the equation 3.32, we have

$$u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$$

Because $y = w^n - u^n$ and $w^n = \frac{p^n}{3u^n}$, we obtain $y = \frac{p^n}{3u^n} - u^n$. Thus, since $x^* = \bar{x} - y$, we have

$$x^* = \bar{x} - \frac{p}{3u^n} + u^n$$
$$k^* = \frac{\delta(\bar{x} - x^*)^2}{2\nu}$$

where, $u^n = (\frac{q^n}{2} \pm \sqrt{\frac{q^{n2}}{4} + \frac{p^{n3}}{27}})^{\frac{1}{3}}$, $p^n = -\frac{[2(N+1)b+4\gamma]\nu}{\delta^2}$ and $q^n = \frac{[2(N+1)b+4\gamma]\nu\bar{x}-2a\nu}{\delta^2}$.

Socially optimal equilibrium

Let us recall the following equation

$$a - 2(Nb+\gamma)x^e - 2\frac{\delta^2}{\nu}(\bar{x} - x^e)^3 = 0$$

Let $t = \bar{x} - x^e$ and rearranging this equation, we have

$$t^3 - \frac{2(Nb+\gamma)\nu}{\delta^2}t + \frac{2(Nb+\gamma)\nu\bar{x} - a\nu}{\delta^2} = 0$$

Following the Cardano method, we let u^e, w^e such that

$$u^{e3} - w^{e3} = q \text{ and } u^e w^e = \frac{p^e}{3}$$

where, $p^e = -\frac{2(Nb+\gamma)\nu}{\delta^2}$ and $q^e = \frac{2(Nb+\gamma)\nu\bar{x} - a\nu}{\delta^2}$.
Let $t = w^e - u^e$. Then, we have

$$(w^e - u^e)^3 + 3u^e w^e(w^e - u^e) + (u^{e3} - w^{e3}) = 0 \tag{3.33}$$

Since $u^e w^e = \frac{p^e}{3}$, then $w^e = \frac{p^e}{3u^e}$ and $u^{e3} - \frac{p^{e3}}{27u^{e3}} = q^e$. By substituting u^e, w^e into the equation 3.33, we have

$$u^e = \left(\frac{q^e}{2} \pm \sqrt{\frac{q^{e2}}{4} + \frac{p^{e3}}{27}}\right)^{\frac{1}{3}}$$

Because $t = w^e - u^e$ and $w^e = \frac{p^e}{3u^e}$, we obtain $t = \frac{p^e}{3u^e} - u^e$. Thus, since $x^e = \bar{x} - t$, we have

$$x^e = \bar{x} - \frac{p^e}{3u^e} + u^e$$
$$k^e = \frac{\delta(\bar{x} - x^e)^2}{2\nu}$$

where, $u^e = (\frac{q^e}{2} \pm \sqrt{\frac{q^{e2}}{4} + \frac{p^{e3}}{27}})^{\frac{1}{3}}$, $p^e = -\frac{2(Nb+\gamma)\nu}{\delta^2}$ and $q^e = \frac{2(Nb+\gamma)\nu\bar{x} - a\nu}{\delta^2}$.

Appendix D: Other figures.

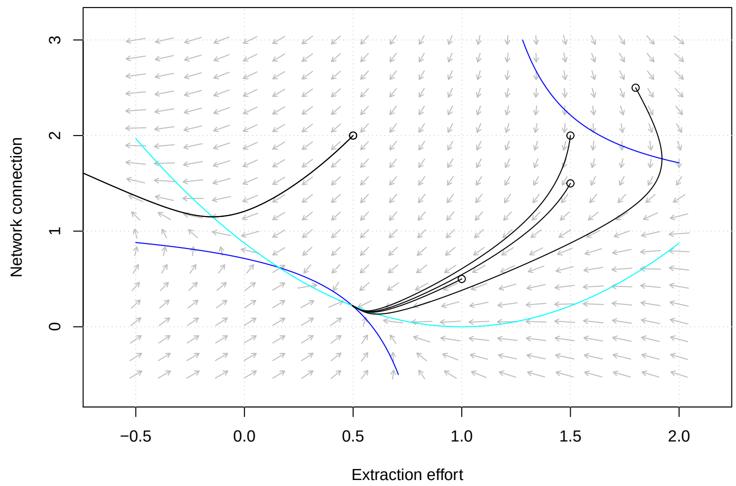


Figure D.1: Two dimensional direction field and trajectories for extraction effort x against network connection k with (x_1^*, k_1^*), (x_2^*, k_2^*) and (x_3^*, k_3^*).

Appendix E: A sequential game.

Let us recall agent i's utility function as follows:

$$U_i(x_i, k_i) = f(X)\frac{x_i}{X} - \gamma x_i^2 - \nu[(N-1)k_i]^2 + \delta k_i(\bar{x} - \tilde{x}_{N_{i(g)}})(\bar{x} - x_i). \tag{3.34}$$

In a sequential game, agents play a two stage game: a common pool game in the first step and then update the network link in the second step (König et al., 2010). Thus, we have to solve the game backward by firstly taking the derivative of Equation (3.34) with respect to k for a given x. Therefore, we have

$$k_i = \frac{\delta(\bar{x} - \tilde{x}_{N_{i(g)}})(\bar{x} - x_i)}{2\nu(N-1)}. \tag{3.35}$$

Substituting the result in Equation (3.35) into the utility function (3.34), we obtain

$$U_i(x_i) = f(X)\frac{x_i}{X} - \gamma x_i^2 - \nu\left[\frac{\delta(\bar{x} - \tilde{x}_{N_{i(g)}})(\bar{x} - x_i)}{2\nu}\right]^2 + \frac{\delta^2}{2\nu}[(\bar{x} - \tilde{x}_{N_{i(g)}})(\bar{x} - x_i)]^2. \tag{3.36}$$

Taking the F.O.C of Equation (3.36) with respect to x_i, we have

$$a - [(N+1)b + 2\gamma]x^* + \frac{\delta^2}{2\nu}(\bar{x} - \tilde{x}_{N_{i(g)}})^2(\bar{x} - x^*) - \frac{\delta^2}{\nu}(\bar{x} - \tilde{x}_{N_{i(g)}})^2(\bar{x} - x^*) = 0. \quad (3.37)$$

At the equilibrium, we would have

$$a - [(N+1)b + 2\gamma]x^* - \frac{\delta^2}{2\nu}(\bar{x} - x^*)^3 = 0. \quad (3.38)$$

Thus, we obtain

$$a - [(N+1)b + 2\gamma]x^* - \frac{\delta^2}{2\nu}(\bar{x} - x^*)^3 = 0 \quad \text{and} \quad k^* = \frac{\delta(\bar{x} - x^*)^2}{2\nu(N-1)}. \quad (3.39)$$

Therefore, solving these system equations, we obtain the same equilibrium solutions as in the case of simultaneous game (see Equations (3.17) and (3.20)).

Chapter 4

Drivers of organic farming: Lab-in-the-field evidence on the role of social comparison and information nudge in networks in Vietnam[1]

4.1 Introduction

Conventional farming is a widely used method worldwide to produce the majority of the food we eat. However, this type of farming technique is currently facing several issues that may threaten its future. It is well known that pesticides and fertilizers lead to serious health problems for consumers and farmers. For example, cancer, one of the most deadly diseases in the world today, is directly linked to pesticide adulteration of the food we eat (Rodgers et al., 2018; Horrigan et al., 2002). From an economic perspective, it is increasingly difficult for conventional farmers to make a living because they have to purchase expensive hybrid seeds, fertilizers and pesticides from outside sources. As a result, organic farming, a type of farming that does not rely on chemicals has been developed as a solution to limit these negative consequences (Huang et al., 2002; Horrigan et al., 2002). Organic farming, which uses locally available natural inputs, avoids chemicals and stays close to nature, produces healthier foods and contributes to consumer well-being. Self-dependency in terms of inputs can increase the profitability of farms. If farming becomes a profitable activity, the migration of populations to cities will decrease. Organic farming can therefore provide many solutions to prevent the destruction of the environment,

[1]This chapter is based on Boun My K., Nguyen-Van P., Pham TKC., Stenger A., Tiet T. and To-The N. (2020), Drivers of organic farming: Lab-in-the-field evidence on the role of social comparison and information nudge in networks in Vietnam, BETA working paper. *Submitted*.

pollution and social imbalances (Liu et al., 2016; Cui et al., 2018). However, organic farming is slow to be adopted today and it may take decades to reach widespread adoption, especially in many developing countries.

In recent years, we have observed a relative increase in the adoption of organic farming in several developed countries due to the heightened awareness of health problems caused by the consumption of contaminated foods and the negative effects of environmental degradation, and, in particular, because of the support from governments and international organizations like the European Union and International Federation of Organic Agriculture Movements (IFOAM)[2] (Reisch et al., 2013). However, in many developing countries, conventional farming is still widely accepted since it helps to provide sufficient food for the population and to generate a surplus for exports, even though this practice is becoming increasingly unsustainable, as revealed by declining crop productivity, environmental degradation, chemical contamination, etc. In certain developing countries like Vietnam, the situation is even worse: farmers use pesticides overtly and without restraint.

According to the report of the Vietnamese Ministry of Agriculture and Rural Development (MARD) (August, 2018), Vietnam imported 79 million USD worth of pesticides and raw materials (about 1,800 billion VND), raising the import value of pesticides and raw materials in the first eight months of 2017 to over 660 million USD (over 15,000 billion VND), an increase of almost 47% over the same period in 2016. Statistics show that Vietnam is importing more and more pesticides and raw materials. The import of pesticides and plant protection chemicals has continuously increased over the last few decades due to the expansion of cultivated areas and the intensive cultivation of many crops. However, excessive use of chemicals in agriculture has caused severe consequences for both the soil and the water, as well as for the quality of agricultural products (Savci, 2012). It is therefore essential to encourage farmers to limit the use of pesticides and to move toward a more sustainable agriculture.

Several studies have shown that the low rate of adoption of organic agriculture is due in part to the lack of information on the part of farmers about the risks of chemical products, as well as to the lack of methods and benefits (Conley and Udry, 2010; Vandercasteelen et al., 2020). Nevertheless, other research has shown that even if farmers personally know that applying more chemicals to their plants is harmful, they are still willing to use pesticides over time to ensure a high level of productivity (Aktar et al., 2009). Government and social media have provided information about the negative effects of chemical inputs, environmental degradation and contaminated food, not only to farmers but to consumers

[2]IFOAM was founded in France in 1972. It has 600 member organizations spread over some 120 countries. IFOAM is involved in a wide range of activities related to organic farming such as the exchange of information, knowledge and reflections among its members.

as well, but, unfortunately, these interventions have not yet had a significant impact on farmers' decisions (FAO, 2017).

This paper aims to examine the factors that influence farmers' decisions in relation to organic farming, focusing on the role of their social network and information nudge, as well as on the role of social comparison between farmers. The first objective of our experiment is to examine whether the social connections among farmers could lead to connections in their behaviors. There is a growing literature on both theoretical and empirical studies that focuses on the impact of networks on individuals' behaviors (Ferguson, 2007; Hogset and Barrett, 2010; Santos and Pacheco, 2011). According to the theory of social and economic networks, individuals link together in a network such as a network of friendship or neighborhood in which they can interact and exchange information with others (Granovetter, 1983; Golub and Jackson, 2010). In agriculture, farmers are often linked to farmers' networks such as neighborhood farmers, friends or agriculture organizations in which they can share information, ideas and reflections on new farming methods. Consequently, social networks could be an effective way to diffuse information related to organic farming (Fafchamps et al., 2020).

Second, we introduce social comparison treatment into the experiment to test how social comparison (i.e., information about the average group investment in organic farming) would impact individual farmers' investment decisions. Some studies have indicated that social concern (e.g., revealing an environmental commitment to the others in the network) can be used as a factor to influence farmers' decisions to adopt organic farming (Dessart et al., 2019; Mzoughi, 2011). In our study, we consider an intra-group comparison in which each farmer observes his or her group's average level of investment. It is assumed that when farmers receive information about the average investment of their groups, a social comparison exists such that an investment that is lower than the average would have a negative impact on farmers' outcomes; inversely, a positive impact is the result of an investment that is higher than the average.

We finally introduce information nudge treatment into the experiment. The idea of using information nudges to shape individual behavior has been aggressively studied in the literature (Hotard et al., 2019; Brandon et al., 2019; Sudarshan, 2017). In our study, we theoretically observe that all farmers would be better off at social optimum, but this optimum is difficult to achieve because every farmer has the incentive to deviate and free-ride on other investments. We thus provide the information nudge about the socially optimal investment of each farmer and the optimal investment of his/her direct neighbor to the other farmers to determine whether or not it would help to encourage farmers to adopt a positive attitude toward organic agriculture.

We tested these ideas via *a contextualized lab-in-the-field* experiment in 2019 with 220 farmers in eight different villages in four different provinces in Northern Vietnam. The context was established on the basis of the definition of organic farming and the fact that we only had farmers not involved in organic farming in our sample. Our experiment was conducted with farmers involved in four different types of networks: circle, star, complete, and not in connection (i.e., empty network). Farmers had to indicate how much they would invest in organic farming in different experimental scenarios (see the 11 scenarios in Figure 4.2). Our main results can be summarized as follows: first, we show that interconnection among farmers affects their decisions in the way that it helps to encourage the investment in organic agriculture. In particular, this impact varies according to the network structure: farmers have a higher incentive to invest in organic farming in a network with more connections than in a network with less connections. Second, the effect of social comparison on the farmer's organic investment also depends on the network structure: we only observe the positive and significant effect of the social comparison treatment in a circle network. Our results suggest that the social comparison treatment performs better in a decentralized network with fewer connections (e.g., a circle network) than the centralized one (e.g., a star network). Finally, our analyses show that social comparison concerns combined with information nudge seem to be a good way to encourage farmers to move toward a more environmentally-friendly agriculture since the information nudge treatment has a positive and significant effect on the organic investment in all network structures.

The remainder of this study is organized as follows. In Section 2, we discuss the theoretical framework and present theoretical predictions. Section 3 describes the *lab-in-the-field* experiment, including treatment, experimental procedure, the sample, and additional experimental questionnaires. Results are presented in Sections 4 and 5. Section 6 is devoted to a discussion and conclusion.

4.2 A network game

4.2.1 Model

Let us consider that there are N agents; a typical agent is denoted by i. Let $\mathbf{D}$ be an $N \times N$ adjacency matrix; its element d_{ij} represents the relationship between i and j. Each agent i has a set of neighbors, denoted $N_i(d)$ (i.e., network of i). In the network of i, $d_{ij} = 1$ if $j \in N_i(d)$ and $d_{ij} = 0$ if $j \notin N_i(d)$. We also assume that the network is *undirected*, which requires that $d_{ij} = d_{ji}$. Thus, a set of neighbors such that i is linked to is referred to neighbors of i: $N_i(d) = \{j \setminus i : d_{ij} = 1\}$ or $N_i(d) = \{j | ij \in g\}$.

Each agent will face a decision problem of how to optimally allocate his or her investment in conventional and organic farming. Let c_i and x_i be the agent i's investment in conventional and organic agriculture, respectively. We assume that the investment is the percentage of lands that an agent can allocate to either conventional or organic agriculture. Thus, each agent's amount of investment is bounded: $c_i \in [0,1]$ and $x_i \in [0,1]$. Since the total investment for each agent is $x_i + c_i = 1$, we can rewrite the investment for conventional farming c_i with a given x_i as $c_i = 1 - x_i$.

Let us consider the case that an agent i invests both in conventional farming (c_i) and organic farming (x_i) so that his/her total gross revenue is the sum of both revenues: $f(c_i) + f(x_i)$. For the sake of simplicity, we can assume that $f(c_i) = \beta f(x_i)$ where $f(.)$ is an increasing and concave function, $f^{'} > 0, f^{''} < 0$ and $f(0) = 0$. We can also assume that the gross revenue in organic farming is higher than the gross revenue in conventional farming, so that $\beta \in (0,1)$. However, to obtain a higher gross revenue in organic farming, farmers have to pay an extra amount γx_i. By substituting c_i with $1 - x_i$, we can write the agent i's total payoff function as follows:

$$\pi_i(x_i) = \beta f(1 - x_i) + f(x_i) - \gamma x_i$$

Social network

In the next step, we extend our model by taking the role of the social network into account. In particular, we consider that social connections exist among farmers and that each farmer cares about the actions of his/her direct neighbors (i.e., peer effect). We assume that the peer effect is positive such that $\delta \sum_j^N d_{ij} x_j x_i$ where $\delta > 0$. This captures the fact that an organic farmer i would benefit from the total organic investment of his or her direct neighbors $\sum_j^N d_{ij} x_j$. Parameter δ, which represents the magnitude of this effect, is assumed to be positive and homogeneous across agents. We can, for instance, imagine that an organic farmer who has good market information might inform his organic peers about when and where to market their crops to receive high profit. The benefits would not only come from the market information but also from experience and greater labor-sharing opportunities in their networks (e.g., farmers in a network can help each other to cultivate organic products) (Munasib et al., 2011). The peer effect can also be interpreted as the descriptive norm in that farmers who adopt sustainable agriculture may motivate their neighborhood farmers to adopt it as well because most individuals are "conditionally cooperative", i.e., people contribute to public goods only if others do so as well (Dessart et al., 2019).

Social comparison

In our model, we also take the social comparison mechanism in which an organic farmer receives information about the average level of organic investment in the network into account (from both direct and indirect neighbors). We assume that farmer i, who invests more in organic farming than the average of his or her group, would earn an amount $\eta(x_i - \frac{1}{N}\sum_j^N x_j)$ where $\eta > 0$, otherwise he or she would lose an amount $\eta(\frac{1}{N}\sum_j^N x_j - x_i)$. From a social perspective, the social comparison could be interpreted as the social factors such as social signaling or social norm, that affect farmers' behaviors. Regarding social signaling, improving public image and status help motivate farmers to adopt more sustainable practices such as organic and integrated farming (Dessart et al., 2019; White et al., 2019). The group's average investment could be seen as a norm or an expected amount of investment. Those who invest more than this level would benefit from social signaling. On the contrary, farmers who invest less than the expected amount of investment would suffer from public punishment (e.g., public shaming).

Considering social network and social comparison concerns, the payoff for agent i is as follows:

$$\pi_i(x_i) = \beta f(1 - x_i) + f(x_i) - \gamma x_i + \delta \sum_j^N d_{ij} x_j x_i + \eta(x_i - \frac{1}{N}\sum_j^N x_j) \tag{4.1}$$

where, $f(x) = ax - bx^2$, $a, b > 0$, $a > 2bx$ and $\delta, \eta > 0$.

If each agent chooses x_i by maximizing his or her payoff, from the first order condition (F.O.C), we then have the Nash equilibrium x^* such that

$$x_i^* = \frac{(1-\beta)a + 2\beta b - \gamma + \eta}{2(1+\beta)b} + \delta \frac{\sum_{j=1}^n d_{ij}}{2(1+\beta)b} x_j^*$$

It should be noted that the game is strategy complementary $\frac{\partial x_i^*}{\partial x_j^*} = \delta \frac{\sum_{j=1}^n d_{ij}}{2(1+\beta)b} > 0$ for $\delta > 0$.

Let $\mathbf{x}^* = (x_1^*, x_2^*, ...x_n^*)$. In the matrix formula, we have

$$\mathbf{x}^* = \frac{\alpha}{2(1+\beta)b}´ + \frac{\delta}{2(1+\beta)b}\mathbf{D}\mathbf{x}^*$$

where, $\alpha = (1-\beta)a + 2\beta b - \gamma + \eta$ and ´ is the $n \times 1$ column matrix of one.
Let $\mathbf{\Phi} = \frac{\delta}{2(1+\beta)b}\mathbf{D}$. If the $\mathbf{\Phi}$ is invertible, we then have the equilibrium that is equal to:

$$\mathbf{x}^* = \frac{\alpha}{2(1+\beta)b}(I - \mathbf{\Phi})^{-1}´. \tag{4.2}$$

Thanks to this closed form solution, we can calculate the equilibrium of each agent based on the information of the given network structure $\mathbf{\Phi}$. In other words, the equilibrium solution varies across different networks, the different positions of the agents inside the network and the number of direct links. Note that the condition of the convertibility of matrix $(I - \mathbf{\Phi})$ can be achieved if the determinant of $(I - \mathbf{\Phi})$ is non-singular. This condition always holds for the circle and complete network because these networks are regular graphs, and according to Hall's theorem, every d-regular graph is invertible (West et al., 2001; Aharoni and Haxell, 2000). Moreover, we can also prove that the determinants of $(I - \mathbf{\Phi})$ for all three network structures (circle, star and complete) are non-zero.[3]

Consider that there is a utilitarian social planner who maximizes the total individual payoffs (considered as social welfare). His or her maximization problem is as follows:

$$\begin{aligned}\max_x W(g,d) &= \max_{x_1,x_2,\ldots,x_N} \sum_{i=1}^{N} \pi_i(x_i,d) \\ &= \max_{x_1,x_2,\ldots,x_N} \sum_{i=1}^{N} \{\beta(a-b) + [(1+\beta)a + 2\beta b - \gamma]x_i \\ &+ \delta \sum_{j=1}^{N} d_{ij}x_i x_j - (1+\beta)bx_i^2 + \eta(x_i - \frac{1}{N}\sum_{j}^{N} x_j)\}\end{aligned}$$

Consequently, according to the F.O.C, the socially optimal investment in organic farming is equal to

$$\hat{\mathbf{x}} = \frac{\hat{\alpha}}{2(1+\beta)b}(I - 2\mathbf{\Phi})^{-1\prime} \tag{4.3}$$

where, $\hat{\alpha} = (1-\beta)a + 2\beta b - \gamma + \eta\frac{N-1}{N}$.

We can observe that for a sufficiently large value of N, $\hat{\alpha} \to \alpha$. Thus, the socially optimal investment $\hat{\mathbf{x}}$ is then higher than the investment at the Nash equilibrium $\mathbf{x}^*$, $\hat{\mathbf{x}} > \mathbf{x}^*$. Since we have $\mathbf{\Phi} = \frac{\delta}{2(1+\beta)b}\mathbf{D}$, a higher value of δ leads to a larger difference between $\hat{\mathbf{x}}$ and $\mathbf{x}^*$. Therefore, in the experiment, we need to impose a sufficiently high value of δ in order to clearly observe the difference between farmers' decisions at the social optimum and at the Nash equilibrium. Note that a higher value of δ also means a stronger impact of the peer effect on individual behavior. A numerical illustration of our theoretical model is discussed in Appendix A.

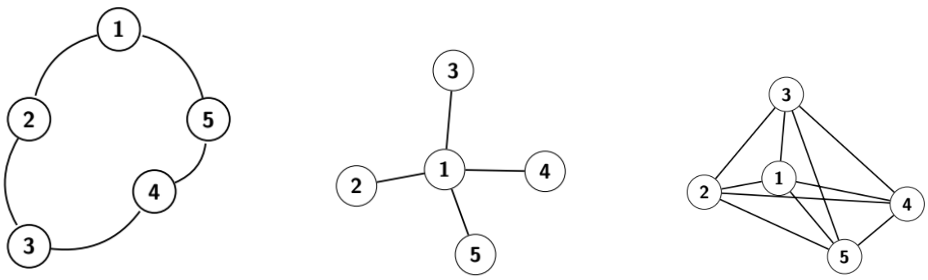
[3] In particular, $det(I - \mathbf{\Phi}) = 0.9389$ for the circle network, $det(I - \mathbf{\Phi}) = 0.9506$ for the star network and $det(I - \mathbf{\Phi}) = 0.8467$ for the complete network with parameter assumptions in the Appendix (see Table A.1).

4.2.2 Theoretical predictions

According to Equation (4.2), the equilibrium of organic investment depends on two terms: the fraction $\frac{\alpha}{2(1+\beta)b}$ and the network structure $\mathbf{\Phi} = \frac{\delta}{2(1+\beta)b}\mathbf{D}$. This suggests that the interconnections among farmers (adjacent matrix **D**) would have a positive impact on farmers' organic investment decisions since $\delta > 0$, which means that an agent who is connected to more organic neighbors (i.e., a neighbor who invests in organic farming) is more likely to invest in organic farming. In addition, the farmers' organic investment would also vary across different types of network structures, which are represented by the matrix **D**. We therefore establish our first prediction as follows:

Prediction 1 (role of networks): Interconnection among agents via their social networks positively impacts their investment in organic farming. This impact varies across three different types of networks: star, circle, and complete.

In the experiment, we test our results with three different types of networks: a star, circle and complete network (see Figure 4.1). The complete network is a decentralized network, which is the simplest situation in real life, where farmers care about the behaviors of all other farmers in their groups/communities. The circle network is also a decentralized one but with fewer connections, in which each farmer cares only about his/her two closest neighbors (i.e., two most important neighbors/friends). Concerning the star network, it is a centralized network in which farmers care about the most important farmer in the network, the central farmer (i.e., the center). According to the theoretical model, we expect that network connections would have a positive impact on individual behavior and that the strongest impact on farmers' organic investments would come from the complete network since it is the most connected network in this study.



(a) Circle **(b)** Star **(c)** Complete

Figure 4.1: The three different network structures for $N = 5$.

Remark that the effect of social comparison on the equilibrium is captured by the parameter η. A higher value of η results in a higher equilibrium level of investment x^* (see Equation 4.2). Thus, we would expect that social comparison has a positive impact on farmers' organic investments. Since the effect of social comparison is independent of the network structure at the equilibrium (Equation (4.2)), we would expect no significant difference in the effect of social comparison on individual behavior across networks. Our second prediction is as follows:

Prediction 2 (role of social comparison): Social comparison has a positive impact on farmers' investments in organic farming. This impact is independent of network structure.

We observe that when optimal investment is higher than its equilibrium level, i.e. $\hat{x} > x^*$, then the farmers' payoffs at the social optimum are also higher than their payoffs at the Nash equilibrium. This means that all farmers would be better off if they coordinated at the social optimum. However, this Pareto optimum will not be easily achieved because farmers have incentives to deviate from the social optimum and earn higher payoffs if they know that others are coordinating at the social optimum (see Table A.1 in Appendix A for a numerical illustration). Thus, it is necessary to verify whether introducing the nudge information would increase the coordination among farmers. In our experiment, the nudge information (i.e., information about the socially optimal investment) is introduced in the case where farmers receive the social comparison treatment since we want to compare the effectiveness of social comparison and the combination effect (with both social comparison and information nudge) in promoting organic agriculture. This leads us to the following prediction:

Prediction 3 (role of social comparison combined with information nudge): Combining social comparison and information nudge has a positive impact on farmer's organic investments. This impact varies across different network structures: star, circle and complete.

4.3 The lab-in-the-field experiment

4.3.1 Treatments

There are two treatments in our experiment: social comparison (Sc) and the combination of social comparison and nudge (ScNd). The control is the *no treatment*, i.e., neither social comparison nor the combination of social comparison and nudge. We test these two treatments and the control in four different types of network structures (empty network, circle, star and complete network).

Treatment variables	Empty network (B)	Network		
		Complete (Cp)	Circle (Cr)	Star (St)
No treatment (N)	-	Cp	Cr	St
Social comparison (Sc)	BSc	CpSc	CrSc	StSc
Social comparison and Nudge (ScNd)	BScNd	CpScNd	CrScNd	StScNd

Figure 4.2: Two treatments and control in four different types of networks (11 scenarios).

The control is the *no treatment* where subjects were invited to participate in a land management game without social comparison and nudge but, even then, a network effect exists that influenced the subjects' payoffs depending on the network structure (star, circle or complete network). We tested a total of 11 different scenarios in the experiment (see Figure 4.2). These 11 scenarios were tested during 22 different experimental sessions, which means that each scenario was tested twice and only one scenario was tested in each session. In the treatment "social comparison" (Sc), information about the average group investment was given. Hypothetically, subjects' payoffs are negatively (or positively) affected by the average group investment if their organic investments are lower (or higher) than the average. In the treatment "social comparison and nudge" (ScNd), subjects receive both information about the average group investment and the information nudge, where the nudge for subjects is provided through information about the socially optimal investment for them and for their direct neighbors.

4.3.2 Experimental procedure

The experiment was initially run with a pilot in June 2019, followed by the field experiment in August 2019. The pilot was run with two groups of farmers (five subjects per group). In the pilot, farmers were assigned to a complete network and the "ScNd" treatment. The objective of the pilot was to test some outcomes of the theoretical predictions, our parameter assumptions, as well as the experimental instructions. The experiment was conducted using an IPad for each participant.[4]

The experiment consisted of four parts. The first part, identical for all sessions, aimed at capturing the subjects' sensitivity to risk. The second part, also identical for all sessions, concerned the case of the empty network (B), no social comparison and no nudge (N) (i.e., no treatment) (see Figure 4.2). The third part of the experiment differed from one scenario to another (see Figure 4.2). In the last part of the experiment, qualitative and quantitative information was collected from the subjects using survey questions. This part was identical for all sessions. More details will be discussed in Section 3.4.

[4]There were ten assistants during the experiment to help farmers use the IPad and to understand the experimental instructions.

At the beginning of the experiment, subjects were invited to read the experimental instructions and the experimenters explained the different parts as well as the monetary incentives. The experimenters and assistants helped the subjects to understand the instructions after they read them. They then had to answer a quiz to test their understanding of the instructions. All instructions are available in the Supplementary Materials.

In the first part of the experiment, we ran a lottery-choice task to capture the subjects' sensitivity to risk. Each farmer was given 50,000 VND (Vietnam Dong)[5] to invest in a lottery. Subjects made their decisions on the IPad screen (see an example in Figure 4.7 in Appendix B). At the end of the experiment, subjects were invited to individually make a draw (by tossing a coin), and the lottery winner was the one who had chosen heads. Subjects were told at the beginning of the first part that lottery winners would receive a triple amount of their investment; otherwise, they would lose the investment and keep the amount that was not invested. The amount of money not invested is used as a relative indicator of risk aversion.

In the second part, subjects were invited to participate in a simple organic investment game. In particular, each farmer was given a similar amount of agricultural land (denoted L). They were invited to allot a proportion of their land to organic farming (denoted as X and ranging from 0% to 100%), and the rest of the land that was not allotted to organic farming was devoted to conventional farming ($L - X$). For each unit of X, the farmer's payoff was calculated using Equation (4.1) and the parameter assumptions in Table A.1. Note that farmers earned 500 VND for each unit of payoff. Thus, individual payoffs (in terms of VND) are given by the following function:

$$\pi = 40,000 + 75,000X - 90,000X^2$$

In this part, there was no peer influence, no social comparison and no information nudge. Depending on their level of investment (X), farmers could receive a payoff ranging from 40,000[6] (for $X = 0$) to 55,625[7] (for the Nash or optimal investment $X = 41.67\%$). Subjects did not receive any information about the optimal decision and payoff nor about the payoff range. Subjects were told that their outcomes depended only on their personal decisions. The experiment was repeated over five periods and subjects could observe their payoffs in each round (for an example, see Figure 4.8 in the Appendix).

The third part of the experiment concerns one of the 11 scenarios mentioned in Figure 4.2. There was a total of 22 experimental sessions since each scenario was tested twice

[5] equivalent to almost 2 USD.
[6] equivalent to 1.7 USD.
[7] equivalent to 2.4 USD.

in two different villages. In each session, there were two groups of subjects (five subjects per group) and all of them were assigned to the same scenario.

In the presence of a network, experimenters informed subjects that organic farmers would benefit from their direct peers organic investment and that the benefit gains depended on the network structure (star: “St", circle: “Cr" and complete: “Cp"). For example, in the star network, the payoff function of farmer 2 (see the network structure in Figure 4.1) is written as follows:

$$\pi_2 = 40,000 + 75,000X_2 - 90,000{X_2}^2 + 20,000X_2X_1, \tag{4.4}$$

where, X_1 is the investment in organic farming of farmer 1. Farmer 1, central farmer in the star network, is farmer 2’s direct neighbor.

For the treatment "Social comparison" (Sc), each subject received the information about the average investment of their group. As previously mentioned, we assumed that for an investment lower than the average, there is a negative impact of social comparison on the outcome, and for an investment higher than the average, the effect of social comparison on the outcome is positive. For farmer 2 concerned by social comparison in the star network, his or her previous payoff function (Equation (4.4)) becomes:

$$\begin{aligned}\pi_2 =& 40,000 + 75,000X_2 - 90,000{X_2}^2 + 20,000X_2X_1 \\ &+ 10,000(X_2 - (X2 + X_1 + X_3 + X_4 + X_5)/5).\end{aligned} \tag{4.5}$$

If we consider the circle network, π_2 is written as follows:

$$\begin{aligned}\pi_2 =& 40,000 + 75,000X_2 - 90,000{X_2}^2 + 20,000X_2(X_1 + X_3) \\ &+ 10,000(X_2 - (X2 + X_1 + X_3 + X_4 + X_5)/5),\end{aligned} \tag{4.6}$$

where, X_1 and X_3 are the investment in organic farming of farmers 1 and 3 (farmer 2’s direct neighbors in the circle network).

For the treatment “social comparison and information nudge" (ScNd), subjects received their peers’ benefits depending on the network structure, as well as the information about the average group investment. The presence of an additional information nudge means that nudged farmers receive information about themselves and their direct neighbors’ socially optimal level of investment. Each farmer then decides to follow or not this information given that if everyone follows this suggestion, every farmer in the group will receive the highest payoff. Similar to the second part, each participant can make a simulation of their decision and see their expected payoff (for an example, see Figure 4.9 in the Appendix).

Note that in the second and third part of the experiment, we chose a repeated game design in which subjects make repeated decisions in a single treatment, with earning feedback provided between rounds. The game was repeated five times for the second part and ten times for the third part. After each round, depending on the different network structures, subjects who were assigned to a particular network structure received the feedback of their direct neighbors' decisions. For instance, subjects in the circle network can observe the investment decision of their two direct neighbors, while those in the complete network have four direct neighbors and consequently receive the feedback of four other farmers' decisions. In the presence of treatments, subjects who were assigned to the "Sc" and "ScNd" treatments received the information about the average group's investment after each round. Subjects who were assigned to the "ScNd" treatment received additional information about the socially optimal investment of all members in their group at the beginning of each round. Primary experimental instructions are described in Appendix B.

4.3.3 Additional experimental questionnaires

In addition to the primary experiments, we collected information from participants on a variety of socio-demographic characteristics. In particular, we collected information on age, gender, farm size, household size, type of residence, individual and household income, health, highest level of education, marital status, number of children in the household, and individual attitudes toward risks, etc.

We also elicited information on a number of questions related to environmental concerns via 15 New Ecological Paradigm (NEP) questions to help us to identify the individual perceptions toward the environment (details of the NEP questions in Table C.3 in the Appendix) (Dunlap et al., 2000). The total NEP score is the aggregate score of these NEP questions, in which Cronbach's alpha is equal to 65.45%[8] and questions number 2, 4, 6, 8, 10, 12, 14 (even number questions) are reversely coded (Cronbach, 1951). There were also several other questions related to environmental concerns in order to capture participants' opinions and concerns toward the environment. All questionnaires are available in the Supplementary Materials.

4.3.4 Sample

In total, 220 farmers took part in the lab-in-the-field experiment. The 22 experimental sessions were divided equally across geographic locations, with ten farmers (five farmers per group) in each experimental session. The participants were all farmers living in rural areas, aged from 16 to 78 years, across eight villages of four different provinces (Vinh Phuc,

[8]Cronbach's alpha is equal to 65.45% in the reliability test, which suggests that 65.45% of the variance in the score is reliable.

Hung Yen, Hai Duong, Ha Noi) in Northern Vietnam (see Figure 5.3 in the Appendix for the area of the experiment). These provinces around Hanoi were chosen because they produced most of the agricultural products (vegetables, rice and fruits) for Northern Vietnam. The experiments were conducted in the village where the participants lived.

Farmers were 52-years-old on average. A total of 67% were women and 39.1% of them were heads of households. They produced mainly vegetables (74.5%) and rice (52.7%). Only 33.2% and 27.7% of the farmers produced fruits and corn, respectively.[9] Most of the farmers in our sample was small household farmers with an average farm size of 2466 m^2. In the next two sections, we will present the descriptive statistics and analyze the average as well as the individual decisions for the 11 scenarios mentioned above.

4.4 An analysis of average investment decisions

In this session, we undertook an analysis of the average investment per network and per treatment. It should be recalled that the decision variable is the proportion of land investment in organic farming, ranging from 0% to 100%. The rest, which is not invested, is devoted to conventional farming. The distribution of the percentage of land invested in organic farming per network and per treatment is shown in Table C.1 (in the Appendix) and in Figure 4.3.

We examine the differences across treatments and networks using the non-parametric test. The Wilcoxon Rank Sum test (or Mann-Whiney U test) was used to compare the choice of participants in two treatments and no treatment across four different networks (Mann and Whitney, 1947). The non-parametric test is presented in Tables 4.1 and 4.2.

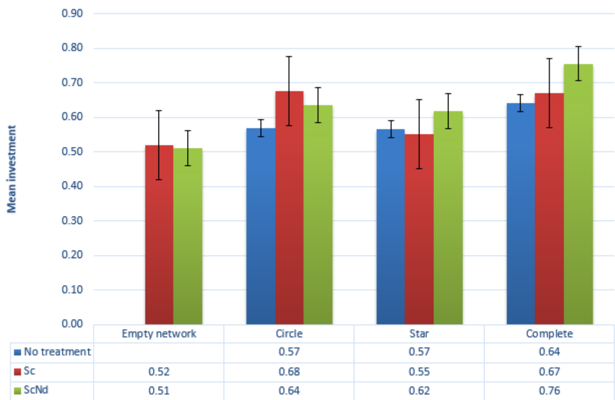


Figure 4.3: Histogram of mean investment per network and per treatment.[10]

[9]Note that the sum of these percentages is greater than 100% since each farmer may produce more than one crop.

Role of networks

In the situation of no treatment, which means that there is no social comparison or information nudge treatment, we observe that farmers invest more in organic farming in the presence of more network connections: on average, 64.1% of the land is invested in organic farming in the complete network in which each farmer is connected to all of the others, while only about 57% of the land is invested in the circle and star network in which there are less connections between farmers (Figure 4.3 and Table C.1 in the Appendix). This result is confirmed by the Wilcoxon Rank Sum test (Table 4.1). In particular, farmers in the complete network invested an average of 7% more in organic farming compared to the circle and star networks.

However, surprisingly, there is no significant difference in organic investment between the circle and the star network (second column of Table 4.1). If we break down the farmers in the star network into two groups - farmers in the center and the corner of the star - we then observe that farmers in the center seem to invest more than the corner ones in organic farming, according to the Wilcoxon test statistic reported in Table C.2 (in the Appendix). The results indicate that farmers in the center invested an average of 10% and 13% more in organic farming compared to the circle and farmers in the corner, respectively. However, there is only one central farmer in the star network. This leads to the fact that the corners have only one direct neighbor (i.e., the network connection is weak) and thus a weaker network (i.e., with fewer connections) results in a lower level of organic investment.

Therefore, in the case without any treatment, we could observe a positive impact of the network on farmers' investment decisions in organic farming. This suggests that farmers seem to be influenced by their direct neighborhood farmers' decisions, and the greater number of direct links/connections means a higher level of organic investment. Prediction 1 is therefore validated.

Table 4.1: Difference-in-mean across the different network structures (Wilcoxon Rank Sum test).

	No treatment			SC			SC & Nudge		
	Circle	Star	Complete	Circle	Star	Complete	Circle	Star	Complete
Empty network	-	-	-	-0.16***	-0.03**	-0.15***	-0.13***	-0.11***	-0.25***
				(0.000)	(0.026)	(0.000)	(0.000)	(0.000)	(0.000)
Circle	-	0.00	-0.07***	-	0.13***	0.01	-	0.02	-0.12***
		(0.858)	(0.000)		(0.000)	(0.778)		(0.179)	(0.000)
Star	-	-	-0.07***	-	-	-0.12***	-	-	-0.14***
			(0.000)			(0.000)			(0.000)

Notes: The table reports the difference-in-mean and the p-value of the Wilcoxon Rank Sum test in parentheses. SC stands for the social comparison.
** $p < 0.05$; *** $p < 0.01$.

[10] Sc stands for "social comparison" treatment. ScNd stands for "social comparison and information nudge" treatment.

Role of social comparison

In the presence of social comparison where farmers received information about their average group investment after each round, the circle and complete networks result in a sufficiently high level of organic investment (about 68% for the circle network and 67% for the complete network compared to 57% and 64% in the case without social comparison) (Figure 4.3). Figure 4.5 suggests that the social comparison treatment works effectively in the circle and complete networks (decentralized network) but that it is less effective in the star network (centralized network). Farmers in the star network invest just a little in organic agriculture (only 55.1% on average). Our theoretical prediction indicated that the effect of social comparison on farmers' decisions does not depend on the network structure. However, we observe that this is not the case in the experiment, even when every farmer in the same network received the same information about his or her group's average investment. One interpretation could be that in the experiment, in addition to the information about the average group investment, farmers who were assigned to the "Sc" treatment received different types of feedback about their direct neighborhood investment depending on the network structure. For instance, farmers in the complete network could observe all of the others' decisions, while those in the circle network could only observe the decisions of two direct neighbors. Thus, the social comparison treatment could play an important role in a network with fewer connections.

Table 4.2: Difference-in-mean (Wilcoxon Rank Sum test).

	No network		Circle		Star		Complete	
	SC	SC & Nudge	SC	SC & Nudge	SC	SC & Nudge	SC	SC & Nudge
No policy	-	-	-0.11***	-0.07***	0.02	-0.05***	-0.03	-0.11***
			(0.000)	(0.000)	(0.156)	(0.000)	(0.105)	(0.000)
SC	-	0.01**	-	0.04**	-	-0.07***	-	-0.08***
		(0.013)		(0.043)		(0.000)		(0.000)

Notes: The table reports difference-in-mean and the p-value of the Wilcoxon Rank Sum test in parentheses. SC stands for the social comparison.
** $p < 0.05$; *** $p < 0.01$.

In a star network, after each round, both farmers in the center and corner received information about the average organic investment of their group (i.e., the same information). The difference is that the center had information about the decisions of all the other farmers in the network, while the corners observe only the center's decision. Figure 4.5 (in the Appendix) suggests that because of the asymmetric information, both the centers and corners followed the average group investment. During the last period, the decisions of the corners seemed to converge to the Nash equilibrium (about 55% at the Nash equilibrium), while the centers followed the average group decision instead of choosing the Nash equilibrium strategy, i.e. about 71% of land invested in organic farming (Table A.1 in the

Appendix). This also suggests that the center seems to be more influenced by the average group decision than what was expected from the theoretical prediction.

We can therefore observe that the social comparison treatment works more effectively in a decentralized network with fewer connections (like a circle network) but performs worse in a centralized network (like a star). Therefore, Prediction 2 is only partially validated.

Role of social comparison combined with information nudge

In the case of an empty network, according to the results in Table 4.2, the value 0.01 in the second column suggests that the farmers in the “Sc" treatment invest 1% more in organic farming than the ones in the “ScNd" treatment. This difference is statistically significant at the 5% level, which is suggested by the Wilcoxon Rank Sum test with the $p - value = 0.013$. This means that in the case of an empty network, the additional information nudge, which is about the socially optimal investment in organic farming, results in a small reduction in investment compared to the social comparison. This observation is in line with our theoretical result that the social optimum (46.11%) is lower than the Nash equilibrium (47.22%) (see Table A.2 in the Appendix).

While the “Sc" treatment performs more efficiently only in the decentralized network (like a circle network), the nudge implementation performs well in encouraging farmers' coordination in all three networks (circle, star and complete network), especially in the complete network with an increase in organic investment up to 76% (see Figure 4.3). This is because farmers are more likely to coordinate with the nudge information in a more strongly connected network (like a complete network) than a weaker connected network (like a circle network). One interpretation could be that in a complete network, each farmer receives nudge information and observes the decisions of all the others (because they are all connected to each other), while in a circle network, each farmer receives nudge information about the optimal decision of two other farmers (who are the two direct neighbors) and also observes only the decisions of these two farmers. Thus, farmers in a complete network are more likely to cooperate with the nudge information when their action is observed by all other farmers in the network (Brick et al., 2017). Consequently, these observations confirm Prediction 3.

4.5 Analysis of individual decisions

In this section, we analyze the impact of different treatments on the individual decisions, x_i. We adopt the fractional regression model to deal with dependent variable, which is defined on the closed interval $x_i \in [0, 1]$ (Papke and Wooldridge, 1996; Ramalho et al., 2011). Figure 4.4 presents the distribution of individual investment decisions across different network structures.

The fractional model with the dependent variable x_i as a fraction bounded between zero and one, i.e., $x_i \in [0, 1]$, has the following structure:

$$E(x_i|Z_i) = H(Z_i\beta), \tag{4.7}$$

where Z_i represents a set of regressors including explanatory variables (Exp_i), socio-economic control variables ($Socio_i$) and psychological control variables (Psy_i). For the logistic link-function $H(.)$ satisfying $0 < H(.) = \frac{exp(.)}{1+exp(.)} < 1$ (Wooldridge, 2009), the fractional logistic model can be written as follows :

$$E(x_i|Z_i) = \frac{e^{Z_i\beta}}{1 + e^{Z_i\beta}}. \tag{4.8}$$

The proposed estimator for β is the Quasi Maximum Likelihood Estimator (QMLE), which maximizes the following Bernoulli log-likelihood function (McCullagh, 1989):

$$l_i(\beta) = x_i log[H(Z_i^{'}\beta)] + (1 - x_i)log[1 - H(Z_i^{'}\beta)]. \tag{4.9}$$

Since there is the non-linear estimation of the conditional mean, the fractional logit model perform well if there are not many observations at the boundary levels; otherwise, two-part models are often a better solution (Ramalho et al., 2011). We observe that the majority of individual investments fall inside the interval $(0, 1)$ and only some small proportion of organic investment is left censored at 0% and right censored at 100% (see Figure 4.4). Additionally, the estimation results with the Tobit regression model are also reported in Table C.5 (in the Appendix).

4.5.1 Descriptive statistics

The dependent variable is the individual decision, or the percentage of individual organic investment ranging from 0 (0%) to 1 (100%). In the fractional logit model, we specify the set of regressors as $Z_i = (Exp_i, Socio_i, Psy_i)$. The descriptive statistics of our variables are reported in Table 4.3.

Table 4.3: Descriptive statistics.

	Mean	Std.Dev	Min	Max
Dependent variables				
Individual decision	0.57	0.19	0	1
Explanatory variables				
Neighbor (t-1)	0.45	0.63	-2.30	1.38
Sc	0.30	0.46	0	1
ScNd	0.24	0.43	0	1
Center	0.04	0.19	0	1
Control variables				
Period	5.5	2.87	1	10
Female	0.67	0.47	0	1
Age (in log)	3.94	0.21	2.77	4.36
Age (in years)	52.40	9.92	16	78
Education				
High school	0.30	0.46	0	1
College/university	0.11	0.31	0	1
Health				
Good	0.40	0.49	0	1
Very good	0.22	0.41	0	1
Individual income				
Medium	0.33	0.47	0	1
High	0.04	0.20	0	1
Farm size (in log)	7.45	0.81	4.99	10.0
Farm size (in m^2)	2466.17	2903.83	147	23,040
Communist	0.18	0.38	0	1
Farmer association	0.88	0.32	0	1
Cooperative	0.68	0.47	0	1
NEP	46.87	4.45	36	63
Risk investment (in log)	10.1	0.82	0	10.8
Organic approval				
Unsure	0.30	0.46	0	1
Agree	0.11	0.31	0	1

The explanatory variables Exp_i include: $Neighbor(t-1)$, the log of total direct neighborhood investment in the previous period; Sc, the social comparison treatment; $ScNd$, the combination of social comparison and information nudge treatment; and $Period$, introduced to capture the time trend (or learning effect).

The socio-economic control variables $Socio_i$ include: $Female$, a dummy that takes a value of 1 if the farmer is female; Age, the log of individual age; $Health$, a category variable that takes the value of 1, 2 or 3 if the individual has bad health, good health or very good health, respectively; *Education*, category variable that takes the value of 1, 2 or 3 if the individual level of education is below secondary school (grade 6 to grade 9), or below vocational school (1 to 2 years after high school), or college and university; *Income*, a category variable that takes a value 1 if the individual is in the low income group (monthly earnings $<$ 4 million VND), a value of 2 if the individual is in the middle income group (monthly earnings from 4 to 8 million VND) and a value of 3 if the individual is in the high income group (monthly earnings $>$ 8 million VND); *Farmsize*, the log of household farmer's farming land (in m^2); and *Communist*, *Farmer association* and *Cooperative*, three dummy variables that take the value of 1 if the individual is a member of the communist party, a farmer's association or a farmer's cooperative, respectively.

The psychological control variables Psy_i include: *NEP*, the aggregate score of individual 15 New Environmental Paradigm questions (Table C.3 in the Appendix); *Risk investment*, the log of individual investment in the lottery choice task (in the first part of the experiment); and *Organic approval*, a category variable that takes the value of 1, 2 or 3 if the individual disagrees/is unsure/agrees, respectively, when the adoption of organic farming is approved by most of the other villagers.

4.5.2 Results

Role of networks

The results in Table 4.4 suggest that in the case of no treatment, $Complete * NoTreat$ has a positive and significant impact on individual decisions compared to the circle network (i.e., $Circle * NoTreat$ is a base category) across the three models in Table 4.4. This result is in line with the results on the average decisions reported in Table 4.1. The results also suggest that the $Star * NoTreat$ is not significantly different compared to the $Circle * NoTreat$, while $Circle * NoTreat$ is positive and statistically significant compared to the empty network. This suggests that farmers are positively influenced by their direct neighborhood's organic investment, even in the case of no treatment. Thus, the network could play an important role in promoting investment in organic farming.

Since the $Neigbor(t-1)$ have different impacts on individual behavior depending on the different network structures (i.e., farmers in different networks and different locations in a particular network have different numbers of direct neighbors), we break down our estimation into four different network structures presented in Table 4.5. We observe that $Neigbor(t-1)$ is statistically significant in all network structures, except for the star network. In the star network, we observe the statistically significant coefficient of $Center * Neighbor(t-1)$. This also suggests that a stronger network connection helps to promote the investment in organic farming.

Table 4.4: Individual decision in organic farming and network structures.

	Fractional regression		
Variables	(1)	(2)	(3)
Empty network*Sc	-0.193***	-0.195***	-0.221***
	(0.067)	(0.066)	(0.068)
Empty network*ScNd	-0.236***	-0.238***	-0.134**
	(0.067)	(0.064)	(0.068)
Circle*Sc	0.463***	0.468***	0.535***
	(0.083)	(0.079)	(0.081)
Circle*ScNd	0.282***	0.284***	0.406***
	(0.079)	(0.075)	(0.073)
Star*NoTreat	-0.007	-0.007	0.007
	(0.071)	(0.066)	(0.071)
Star*Sc	-0.072	-0.072	-0.041
	(0.068)	(0.065)	(0.072)
Star*ScNd	0.207***	0.209***	0.236***
	(0.077)	(0.075)	(0.081)
Complete*NoTreat	0.304***	0.307***	0.289***
	(0.081)	(0.077)	(0.076)
Complete*Sc	0.437***	0.441***	0.380***
	(0.088)	(0.082)	(0.088)
Complete*ScNd	0.853***	0.861***	0.800***
	(0.096)	(0.092)	(0.095)
Period		0.070***	0.070***
		(0.005)	(0.005)
Control variables			
Age (in log)			0.366***
			(0.087)
Education (below secondary as a base category)			
High school			-0.048
			(0.037)
College			-0.163***
			(0.060)
Health (bad health as a base category)			
Good			-0.073*
			(0.039)
Very good			0.185***
			(0.050)
Farm size (in log)			-0.063***
			(0.022)
Cooperative			-0.084**
			(0.040)
Intercept	0.277***	-0.106	-0.724
	(0.060)	(0.066)	(0.522)
Observations	2200	2200	2200
Number of farmers	220	220	220
Log pseudo-likelihood	-1446.20	-1435.84	-1430.95
Wald $\chi^2(q)$	421.05***, q=10	594.86***, q=11	670.53***, q=27
Pseudo R^2	0.016	0.023	0.026

Note: The dependent variable is the individual investment. Regressions with Circle*NoTreat which is circle network with no treatment, is a base category. NoTreat is no treatment. Sc and ScNd stand for the social comparison and social comparison & nudge treatment, respectively. Insignificant control variables are not reported including NEP, Female, Individual income, Risk investment, Communist, Farmer association and Organic approval, which are not statistically significant.
Bootstrapped standard errors in parentheses with 500 bootstrap replications.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

The variable $Neighbor(t-1)$ is not significant in the star network, which indicates that farmers in the corner of the star seem less likely to care about the behaviors of the center, as was expected in our theoretical prediction. Additionally, the variable *Center* is not significant at the 5% level, which means that the center in our sample does not seem to invest more in organic farming compared to the corner farmers. This could be the reason why the star network performs worse than the other networks (e.g., circle and complete network) in encouraging organic farming.

Therefore, Prediction 1 is validated since the results show that a network with more connections (i.e., complete network) is more effective in encouraging organic investment than one with fewer connections.

Role of social comparison

In the presence of the “Sc" treatment, the results in Table 4.4 show that the $Circle * Sc$ and $Complete * Sc$ are positive and significant, while $Star * Sc$ is not significant and $EmptyNetwork * Sc$ is negative and significant. This suggests that the “Sc" treatment plays a role in promoting organic farming but the effects of “Sc" are different in different network structures. This result is also confirmed by the non-parametric test in Table 4.2.

According to the estimation results in Table 4.5, we find that the social comparison treatment is positive and significant only in the circle network. Figure 4.5 shows that social comparison also has a positive impact on individual decisions in both circle and complete networks. This suggests that the social comparison treatment has a positive impact on farmers' investments in organic farming in the complete network, but its impact is not statistically different compared to the case of complete network without treatment.

Our results confirm that in the case of the circle network, farmers who received the social comparison treatment allocated a higher percentage of lands to organic farming than farmers in other types of network structures. It should be noted that the circle and complete network are both decentralized networks, but each agent in the complete network has more connections compared to the circle. While the circle and complete networks are decentralized, the star is representative of the centralized network in which all agents are connected to the center and there is no link between individuals in the corner. In our experiment, each farmer in the circle network only had two direct neighbors and he or she could therefore only observe the investment decisions of two direct neighbors after each round. However, in the complete network, each farmer is linked to all others and he or she could thus observe all the others' investment decisions even without social comparison. In the star network, only the centers could observe all the other farmers' decisions. Thus, this implies that the social comparison does not have a significant impact on the individual investment in organic farming in the star and complete networks. Consequently, Prediction 2 is partially validated: the “Sc" treatment performs better in the decentralized network with fewer connections (like the circle network).

Table 4.5: Summary estimation results.

	Fractional regressions			
Variables	**Empty network**	**Circle**	**Star**	**Complete**
Neighbor (t-1)		0.637***	0.080	0.667**
		(0.147)	(0.109)	(0.333)
Center			-0.568*	
			(0.325)	
Center*Neighbor (t-1)			0.996**	
			(0.409)	
Sc		0.289***	-0.084	0.166
		(0.106)	(0.053)	(0.107)
ScNd	0.008	0.210***	0.143*	0.349***
	(0.051)	(0.092)	(0.080)	(0.101)
Period	0.006	0.054***	0.030***	0.098***
	(0.008)	(0.013)	(0.009)	(0.021)
Control variables				
NEP	0.006	0.014*	-0.017***	-0.016*
	(0.006)	(0.007)	(0.006)	(0.010)
Female	-0.051	-0.144*	-0.494***	0.364***
	(0.058)	(0.082)	(0.089)	(0.101)
Age (in log)	0.346**	0.158	-0.294	1.666***
	(0.141)	(0.207)	(0.216)	(0.292)
Health (bad health as a base category)				
Good	-0.060	-0.099	-0.213***	0.279**
	(0.059)	(0.087)	(0.062)	(0.111)
Very good	0.074	-0.081	-0.108	0.677***
	(0.084)	(0.094)	(0.102)	(0.127)
Risk investment (in log)	0.005	-0.083	0.042	0.394***
	(0.018)	(0.081)	(0.064)	(0.117)
Organic approval (disagree as a base category)				
Unsure	-0.233*	0.209	-0.763***	0.377**
	(0.136)	(0.180)	(0.156)	(0.174)
Agree	0.103*	0.736***	-0.017	-0.478***
	(0.075)	(0.175)	(0.075)	(0.120)
Intercept	-2.101**	-0.744	2.203*	-9.460***
	(0.875)	(1.500)	(1.157)	(1.856)
Observations	400	540	540	540
Number of farmers	40	60	60	60
Log pseudo-likelihood	-276.19	-341.72	-359.45	-311.09
Wald $\chi^2(q)$	104.93***	200.51***	228.51***	248.77***
q	18	20	20	20
Pseudo R^2	0.003	0.029	0.017	0.053

Note: The dependent variable is the individual investment. Regressions with no treatment as a base category. Bootstrapped standard errors in parentheses with 500 bootstrap replications.
Control variables are not reported, including Individual income, Education, Farm size, Communist, Farmer association and Cooperative which are not statistically significant at the 5% level. The detailed estimation results are reported in the Appendix.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Role of social comparison combined with information nudge

We observe that the "ScNd" (social comparison combined with information nudge) treatment does not seem to perform well in the empty network, but provides a positive and significant impact on farmers' investments in organic farming in the presence of a network (Table 4.4). Table 4.4 shows that there is a negative impact of $EmptyNetwork * ScNd$ on individual behavior compared to the baseline which is $Circle * NoTreat$. Moreover, the first column of Table 4.5 confirms this result by indicating that the impact of "ScNd" on individual organic investment in the empty network is negligible. This result is in line with the theoretical prediction that there is no significant difference between the socially optimal investment and the Nash equilibrium in the case of the empty network (Table A.2 in the Appendix).

The results in both Tables 4.4 and 4.5 indicate that in the presence of network connections, the treatment “ScNd" has positive and significant impacts on farmers’ investments in organic farming in all the three networks (circle, star and complete network). This suggests that the “ScNd" treatment performs more efficiently in the presence of network connections than in the empty network. By comparing different networks (e.g., circle, star and complete networks), we observe that the “ScNd" performs extremely well in the complete network compared to the star and circle networks (Table 4.4). This is also in line with our theoretical prediction since the information nudge provided to farmers is the information about the socially optimal investment, and the social optimum in the complete network is higher than the one in the star and circle networks (Table A.1 in the Appendix). This suggests that it would be more efficient to provide the combination treatment to a strongly connected network (i.e., complete network) than a weakly connected one (i.e., circle network) and to a decentralized network (i.e., complete and circle networks) rather than a centralized one (i.e., star network). Additionally, because of the network connection, farmers in the complete network can observe the decisions of all the others after each period of the game, while farmers in the circle and star networks can observe only the decision of their direct neighbors, except for the center in the star network. Thus, it is easier for farmers in complete networks to coordinate in terms of organic investment than others in other networks. Prediction 3 is therefore validated.

For the control variables, some of the control variables (age, education, health, farmer size, belonging to a farmers’ cooperative) can significantly explain the individual decision to invest in organic farming. In particular, older farmers seem to invest more in organic farming than younger ones. Surprisingly, farmers who have college and university degrees in our sample are less likely to care about organic farming than others. Farmers in very good health have a higher incentive to invest in organic farming than other farmers. However, a large farm size, which is a proxy for farming scale, has a negative and significant impact on the individual investment in organic farming. This is perhaps because it is costlier for larger-scale household farmers to convert their lands to organic farming than small-scale ones. Being a member of a farmer’s cooperative does not seem to help farmers to become more aware of organic agriculture. Other variables like NEP, female, risk investment, individual monthly income or belonging to the communist party do not have any significant impact on farmers’ decisions.

4.6 Discussion and conclusion

Our results suggest that more connections (or links) in the network could result in a higher investment in organic farming. This is in line with the literature that reports that participants are more likely to coordinate in the presence of a network structure: a network with more connections is better than one with fewer connections in facilitating coordination (McCubbins et al., 2009). This result suggests that the network-based approach could be considered as a cost-effective method for policymaker to incentivize the adoption of organic agriculture or new environmentally-friendly agricultural practices (Beaman et al., 2018).

As suggested in the existing literature, the intra-group comparison can lead to stronger cooperation in the public good provision (Böhm and Rockenbach, 2013). In our study, we also investigate the effect of intra-group comparison (i.e., social comparison treatment), but in the context of organic farming and in the presence of the network (i.e., connections exist among individuals). We find that the social comparison treatment has a significant impact on farmers' organic investment decisions in organic farming in a circle network. In a complete network, when every farmer can fully observe all other farmers' decisions, providing social comparison treatment cannot sufficiently help to promote the organic investment since the comparison effect among individuals in the network dominates the comparison effect of the social comparison treatment. The results therefore suggest that social comparison can be used to incentivize farmers to cooperate by investing in organic farming more effectively in a decentralized network with fewer connections (like a circle network).

In a network where only one farmer has the advantage of fully observing the others' decisions (i.e., farmers in the center of the star network), social comparison makes those in the center to perform worse than what was expected in our theoretical prediction. In the last period of the game, we observe that the farmers in the center do not seem to play the Nash equilibrium as expected in the theoretical prediction, but that they instead follow the average investment decision of the whole group (i.e., their direct neighbors) (see Figure 4.5). Thus, it would be more interesting for future studies to investigate this issue in greater detail, perhaps with two or more farmers in the center of the network (e.g., a bridge network). In our model, we have only one farmer in the center and this could therefore make them less likely to sustain their behaviors when they observe that all the other farmers in the network have chosen a low level of organic investment.

While social comparison can encourage farmers' pro-environmental decisions only in a decentralized network with fewer connections (i.e., a circle network), social comparison combined with information nudge treatment seems to be a more effective way to encourage farmers to move toward a more environmentally-friendly agriculture. This suggests that the complementarity of social comparison and information nudge (i.e., combination effect) could exceed the effect of social comparison. We also observe a positive and strongly significant impact of the social comparison combined with the information nudge on individual farmers' decisions in the presence of a complete network. This means that farmers in a network with more connections perform better with the combination effect than the one with fewer connections in promoting organic farming.

In order to capture the causal effect of networks on farmers' behaviors, we consider the organic investment game with the given network structures (exogenous network) and allow the network to vary. Future studies should also take the endogenous structure of the network into account in order to capture which network pattern could result in a higher level of adoption of organic agriculture. Our results suggest that there is a possibility of a *crowd in* effect since the effect of both social comparison and information nudge exceeds the effect of social comparison (Brandon et al., 2019). The mechanism of *crowding in and out* in social nudges (social comparison and information nudge) deserves our attention since it may have important implications in promoting sustainable agriculture.

One major issue concerns the recommendations that could be adopted to design public policies. They would be based not only on subsidies but more essentially on information given to farmers (Van Campenhout et al., 2017). Firstly, it is crucial for farmers to understand the importance of their social links. In many instances, neighborhood farmers or local agricultural organizations are valuable sources of knowledge, information and advice for farmers and, consequently, policymakers and/or individuals themselves should always try to establish a channel for local farmers to promote farmer-to-farmer links. Secondly, in reality, it is always very difficult to observe the actual network structure, and farmers cannot normally fully observe the behaviors, actions or decisions of their neighbors. In this situation, providing social comparison treatment like information about the average organic investment of the local groups or communities to farmers could stimulate self-evaluation as well as competition, and could thus help to incentivize farmers to behave positively towards organic farming. Finally, timely reminders about not only the importance of organic agriculture but also the socially optimal organic investment (i.e., information nudge) can help to increase farmers' awareness about organic agriculture and to help them to maintain commitments and schedules (Fabregas et al., 2019). As a result, it helps to nudge them towards bridging the gap between their intentions and their actions.

Appendix A: Theoretical predictions - A numerical illustration.

To illustrate the theoretical model, let us consider a numerical example with the parameter assumption reported in Table A.1. We consider that each farmer will decide to invest the percentage of his or her farming land in organic agriculture, $x \in [0, 1]$ (i.e., from 0% to 100%). We also consider that $\beta = 0.8$, which means that the benefit of organic farming is 20% higher than that of conventional farming. "Cost and benefit analysis" literature suggests that income from organic farming varies from 20-30% higher than conventional farming at a low level of subsidy, and 50% at the highest subsidy level (Urfi et al., 2011). We assume that the parameter of the revenue function $a = 2$ and, thus, given the assumption that $f^{'}(x) \geq 0$, b must be ≤ 1 for $x = 1$. In order to make the game more interesting, we consider that in the absence of a network and social comparison, it is optimal to invest less than 50% of the land in organic farming (i.e., $x^* < 0.5$) and thus it is therefore necessary that $\gamma = 0.5$ since this assumption holds for $\gamma > 0.45$. For the social comparison parameter, we chose $\eta = 0.2$ since the existing literature suggests that the impact of social comparison on individual behavior varies from 20% to 30% (Vogel et al., 2015; Jiang and Ngien, 2020). The peer parameter is equal to 0.4 since δ must be ≥ 0.4 in order to obtain a difference of at least 0.2 in the Nash equilibrium and social optimum in the circle network (Table A.1), which is required for the information nudge treatment, as discussed in our theoretical model in Section 2. Table A.1 (in the presence of social comparison), Table A.3 (in the case of no social comparison) and Table A.2 (in the empty network) present the equilibrium and payoffs associated with two different organic land investment decisions (Nash equilibrium and social optimum) in a five-player game.

Table A.1: Nash equilibrium and social optimum in the presence of social comparison.

Parameter values
Difference in revenue between conventional and organic farming: $\beta = 0.8$.
Parameters of the revenue function $f(x) = ax - bx^2$: $a = 2$ and $b = 1$.
Extra cost for organic investment: $\gamma = 0.5$.
Peer parameter: $\delta = 0.4$.
Comparison parameter: $\eta = 0.2$.
Number of agents per network: $N = 5$.

Equilibrium in the presence of social comparison

		Star		
	Circle	Center	Corner	Complete
Nash equilibrium	0.6071	0.7175	0.5519	0.85
Social optimum	0.83	1.00	0.7023	1.00

Farmer i's payoff

			Star					
Farmer i's choice/ Other farmers' choices	Circle		Center		Corner		Complete	
	Nash	Social	Nash	Social	Nash	Social	Nash	Social
Nash	**134.2***	141.4	**160.9***	175.8	**123.1***	126.4	**193.1***	211.1
Social	124.3	**135.6**^{e}	145.4	**167.1**^{e}	118.4	**123.4**^{e}	188.4	**210**^{e}

Notes: * and ^{e} stand for farmer i's payoff at the Nash equilibrium and the social optimum, respectively.

The results of the Nash equilibrium, social optimum and payoffs are calculated using Equations (4.1), (4.2) and (4.3), respectively. Our results in Table A.1 indicate that this five-player game has a unique Nash equilibrium. In the complete network, the payoff for each farmer at the Nash equilibrium is 193.1. However, the Nash equilibrium is not Pareto optimal. By coordinating at the social optimum, each farmer would earn an amount equal to 210, whereas, this optimum is difficult to achieve because each farmer has the incentive to deviate if he or she knows that the other farmers will choose the optimal strategy. Specifically, farmer i would deviate in order to play at the Nash equilibrium and earn a slightly higher payoff of 211.1. The other farmers would then suffer a loss equal to $210 - 188.4 = 21.6$. Therefore, the dominant strategy is that every farmer coordinates at the Nash equilibrium and earns a payoff equals to 193.1. Similarly, the same logic is applied to the circle and the star networks. However, in the case of the empty network, we observe that the Nash equilibrium is higher than the social optimum in the presence of social comparison. This is because there is a negative externality of the social comparison.

Table A.2: Nash equilibrium and social optimum in the empty network.

Equilibrium in the empty network				
	No social comparison		Social comparison	
Nash equilibrium	0.4167		0.4722	
Social optimum	0.4167		0.4611	
Farmer *i*'s payoff				
Farmer *i*'s choice/ Other farmers' choices	No social comparison		Social comparison	
	Nash	Social	Nash	Social
Nash	**111.3***	111.3	**110.7***	110.9
Social	111.3	**111.3**^{e}	110.7	**110.9**^{e}

Notes: Equilibrium and payoffs are calculated with the same parameter as in the case of presence of social comparison.
* and ^{e} stand for farmer *i*'s payoff at the Nash equilibrium and the social optimum, respectively.

Because of the sub-optimality of the Nash equilibrium, our objective is to introduce the information nudge about the socially optimal level of investment to the farmers in the experiment in order to examine whether the nudge treatment could help to encourage farmers to move toward a more sustainable agriculture.

Table A.3: Nash equilibrium and social optimum in the case of no social comparison.

Equilibrium in the case of no social comparison								
			Star					
	Circle		Center		Corner		Complete	
Nash equilibrium	0.5357		0.6331		0.4870		0.75	
Social optimum	0.75		0.9807		0.6346		1.00	
Farmer *i*'s payoff								
			Star					
Farmer *i*'s choice/ Other farmers' choices	Circle		Center		Corner		Complete	
	Nash	Social	Nash	Social	Nash	Social	Nash	Social
Nash	**131.7***	140.8	**152.2***	167.1	**122.7***	129.5	**181.3***	211.3
Social	123.4	**136.3**^{e}	130.4	**153.6**^{e}	118.8	**127.6**^{e}	170	**210**^{e}

Notes: Equilibrium and payoffs are calculated with the same parameter as in the case of the presence of social comparison.
* and ^{e} stand for farmer *i*'s payoff at the Nash equilibrium and the social optimum, respectively.

It should be noted that in Tables A.1-A.2, in order to facilitate the computation as well as the theoretical analysis, we assume that all agents are identical. In this case, all of the agents' direct and indirect neighbors (four other agents) play the same strategies at the equilibrium. Indeed, the real situation would be more complicated if all of the agents' strategies were different. However, this assumption still makes sense in reality because when making their decisions, agents usually take what both direct and indirect neighbors would do into account. In the experiment, agents participate in a ten-period repeated game. In the case of no social comparison, agents can observe the previous decision of their direct neighbors after each round. For instance, agents in the circle observe the decisions of two direct neighbors, while those in the complete network observe the decisions of four direct neighbors. In the presence of social comparison, agents will receive additional information about the average group organic investment. The information nudge provides agents with information about the optimal investment strategy at the beginning of each round. In this way, we can explore the impact of information about their neighbors' previous choices on their likelihood of choosing the Nash equilibrium strategy and coordinating on the socially optimal outcome.

Appendix B: Primary experimental instructions.

One week before the experiment, the local authorities in each village contacted farmers either directly or by sending letters to invite them to the experiment without knowing its content.

Upon arrival at the experimental session, farmers were given the detailed information about the experiment and the monetary incentives. The farmers were informed that they would be paid after participating in the survey and one farmer would receive at least 120,000 VND[11] depending on their performances.

The first part of the experiment was a lottery choice task described above. In the second part of the experiment, farmers were told that their investment would not affect any of the others' decisions and that their payoffs depended only on their personal level of investment. Before starting the second part in which the simple organic investment game was played, experimenters introduced the definition of organic farming to the farmers. The definition is written as follows:

> "Organic agriculture is a production method that excludes the use of most chemicals (such as pesticides and fertilizers often used in conventional agriculture since the beginning of the 20th century), GMOs (Genetically Modified Organisms) and crop preservation by irradiation. Organic farming contributes to reducing environmental impacts (for example, by reducing water pollution and protecting soil fertility, etc.) and improving food quality."

In the third part, farmers were informed that each individual was assigned to a position in a particular network of five participants (star, circle, complete or empty network). There were two groups per session (since there were ten participants per session). Only the farmers knew their positions and thus nobody had any information about who would be their neighbors (either direct or indirect) or which group they were in. This position would be fixed determined all ten periods of the experiment. Experimenters also explained the particular network structure that they were assigned to, and the direct and indirect neighbors/links. They were also informed that there were peer effects due to the network links. Farmers would benefit from their direct neighborhood investments. They were told that there would be feedback after each round and that each farmer could observe the investment decision of his or her direct neighbors. The explanation of the role of networks is summarized as follows:

> "Organic farmers would benefit from the total organic investment of their direct neighbors. This benefit would be the result of the market information that

[11] equivalent to about 5 USD.

> an organic farmer who has good market information might share with his organic peers about when and where to market their crops to receive high prices. The peer benefits would also come from positive experiences and considerable labor-sharing opportunities in their networks. From a social perspective, farmers who adopt organic agriculture may motivate their neighboring farmers to adopt it as well because most individuals are "conditionally cooperative"."

In the presence of social comparison (Sc), experimenters informed farmers that there would be the peer effects depending on the network structures (star, circle or complete network) and the social comparison. The peer effect was explained in the same way as previously described. After each round, there was also feedback and each farmer would receive the information about his or her group's average investment decision. Regarding the social comparison, it was explained as follows:

> "Farmers would receive information about the average organic investment of the total group (including themselves and their direct and indirect neighbors) after each round. Organic farmers who invested less would then suffer a negative impact on the payoff. This negative impact would be calculated accordingly by the given payoff function".

In the presence of an information nudge (ScNd), farmers were informed that information would appear on the screen at the beginning of each round: their optimal investment as well as that of all the other farmers in their group. If every farmer followed the instruction to choose the optimal level of investment, then all farmers would earn the optimal profit/payoff. This information would appear every time at the beginning of each round. For example, in the star network, the information was displayed as follows:

> "The optimal decision for the whole group is: player 1 chooses X equal to 100% and four other players choose X equal to 70.23%".

They can decide to follow or not this information. After each round, farmers would receive feedback concerning information about the investment decision of their direct neighbors.

Appendix C: Additional experimental results.

Table C.1: Mean investment per network and per treatment.

	Empty network	Circle	Star	Complete
No treatment	-	0.568	0.567	0.641
		(0.197)	(0.132)	(0.190)
Sc	0.520	0.677	0.551	0.671
	(0.111)	(0.185)	(0.115)	(0.220)
ScNd	0.510	0.636	0.618	0.756
	(0.112)	(0.176)	(0.175)	(0.193)

Notes: The standard deviation is in parentheses. Sc stands for "social comparison" treatment. ScNd stands for "social comparison and information nudge" treatment.

Table C.2: Difference-in-mean across different network structures and the center/corner of the star network (Wilcoxon Rank Sum test).

	No treatment			Sc			ScNd		
	Center	Corner	Complete	Center	Corner	Complete	Center	Corner	Complete
Circle	-0.10***	0.03	-0.07***	0.12***	0.13***	0.01	-0.06**	0.04**	-0.12***
	(0.000)	(0.094)	(0.000)	(0.000)	(0.000)	(0.778)	(0.048)	(0.016)	(0.000)
Center	-	0.13***	0.03	-	0.01	-0.11***	-	0.10***	-0.06
		(0.000)	(0.595)		(0.435)	(0.000)		(0.000)	(0.171)
Corner	-	-	-0.10***	-	-	-0.12***	-	-	-0.16***
			(0.000)			(0.000)			(0.000)

Notes: The table reports the difference-in-mean and the p-value of the Wilcoxon Rank Sum test in parentheses. Sc stands for "social comparison" treatment; ScNd stands for "social comparison and information nudge" treatment. Center and corner are presented for the subset of only center and corner farmers in the star network.
** $p < 0.05$; *** $p < 0.01$.

Table C.3: The 15 NEP scale items and their response distributions (in percentage).

NEP scale items	Strongly disagree	Partly dis-agree	Unsure	Partly agree	Strongly agree	Corr
1:"We are approaching the limit of the number of people the earth can support".	7.27	39.09	4.55	35.00	14.09	0.441
2:"Humans have the right to modify the natural environment to suit their needs".[a]	6.36	14.55	0.45	55.45	23.18	0.535
3:"When humans interfere with nature, it often leads to disastrous consequences".	6.82	44.09	3.64	33.64	11.82	0.466
4:"Human ingenuity will ensure that we do not make the earth unlivable".[a]	2.73	10.00	3.18	62.27	21.82	0.419
5:"Humans are severely abusing the environment".	6.36	25.91	2.27	41.82	23.64	0.387
6:"The Earth has plenty of natural resources if we just learn how to develop them".[a]	2.73	1.36	1.36	58.18	36.36	0.456
7:"Plants and animals have as much right as humans to exist".	0.91	5.00	1.82	56.82	35.45	0.485
8:"The balance of nature is strong enough to cope with the impacts of modern industrial nations".[a]	14.55	44.55	6.36	26.82	7.73	0.340
9:"Despite our special abilities, humans are still subject to the laws of nature".	0.45	4.09	1.82	53.64	40.00	0.414
10:"The so-called "ecological crisis" facing humankind has been greatly exaggerated".[a]	2.27	45.91	10.00	35.00	6.82	0.356
11:"The Earth is like a spaceship with very limited room and resources".	0.45	12.27	3.64	59.09	24.55	0.375
12:"Humans were meant to rule over the rest of nature".[a]	3.64	24.55	5.91	52.27	13.64	0.380
13:"The balance of nature is very delicate and easily upset".	1.82	19.09	5.91	64.09	9.09	0.390
14:"Humans will eventually learn enough about how nature works to be able to control it".[a]	2.73	15.00	1.82	65.45	15.00	0.399
15:"If things continue on their present course, we will soon experience a major ecological catastrophe".	0.91	8.18	3.18	63.18	24.55	0.485
Total NEP score.			Mean = 46.87 and SD = 4.455. Cronbach's alpha = 0.6545			

Notes: [a] Reverse coded.
The column Corr represents the item-total correlation, which tells us how much each item correlates with the total NEP score. Cronbach's alpha is equal to 65.4% in the reliability test, which suggests that 65.4% of the variance in the score is reliable.

Table C.4: Correlation matrix of explanatory variables by different networks (with Pearson's correlation test).

	Empty network	Circle network		Star network			Complete network	
	Sc	Neighbor(t-1)	Sc	Center	Neighbor(t-1)	Sc	Neighbor(t-1)	Sc
Center	-	-	-	1.00	-	-	-	-
Neighbor(t-1)	-	1.00	-	0.83	1.00	-	1.00	-
				(0.00)				
Sc	1.00	0.21	1.00	0.00	0.00	1.00	-0.06	1.00
		(0.00)		(1.00)	(0.93)		(0.150)	
ScNd	-0.15	0.06	-0.50	0.00	0.06	0.5	0.18	-0.50
	(0.00)	(0.166)	(0.00)	(1.00)	(0.117)	(0.00)	(0.00)	(0.00)

Notes: The p-value of the Pearson correlation test statistics are in parentheses.
The Pearson correlation test statistics suggest that there are correlations between the "Sc" and "ScNd" treatments and between direct neighborhood investment $Neighbor(t-1)$ and Center. However, the correlation coefficients of these variables are not too large, except for the correlation between center and $Neighbor(t-1)$ in the star network.

Table C.5: The full estimation results.

	Empty network		Circle		Star		Complete	
Variables	Tobit	Fractional	Tobit	Fractional	Tobit	Fractional	Tobit	Fractional
Neighbor (t-1)			0.149***	0.637***	0.019	0.080	0.176**	0.667**
			(0.034)	(0.147)	(0.026)	(0.109)	(0.070)	(0.333)
Center					-0.113	-0.568*		
					(0.073)	(0.325)		
Center*Neighbor (t-1)					0.206**	0.996**		
					(0.090)	(0.409)		
Sc			0.067***	0.289***	-0.020	-0.084	0.038*	0.166
			(0.021)	(0.106)	(0.012)	(0.053)	(0.022)	(0.107)
ScNd	0.002	0.008	0.048**	0.210***	0.033*	0.143*	0.090***	0.349***
	(0.012)	(0.051)	(0.019)	(0.092)	(0.018)	(0.080)	(0.020)	(0.101)
Period	0.001	0.006	0.012***	0.054***	0.007***	0.030***	0.020***	0.098***
	(0.002)	(0.008)	(0.003)	(0.013)	(0.002)	(0.009)	(0.004)	(0.021)
Control variables								
NEP	0.001	0.006	0.003*	0.014*	-0.004***	-0.017***	-0.003*	-0.016*
	(0.001)	(0.006)	(0.001)	(0.007)	(0.001)	(0.006)	(0.002)	(0.010)
Female	-0.012	-0.051	-0.030*	-0.144*	-0.105***	-0.494***	0.077***	0.364***
	(0.014)	(0.058)	(0.017)	(0.082)	(0.023)	(0.089)	(0.022)	(0.101)
Age (in log)	0.085**	0.346**	0.036	0.158	-0.062	-0.294	0.378***	1.666***
	(0.035)	(0.141)	(0.043)	(0.207)	(0.051)	(0.216)	(0.056)	(0.292)
Education (below secondary as a base category)								
High school	0.026*	0.107**	0.048*	0.202*	-0.001	0.004	-0.023	-0.120
	(0.013)	(0.054)	(0.024)	(0.120)	(0.016)	(0.065)	(0.021)	(0.111)
College	0.058**	0.235**	-0.035	-0.121	-	-	-0.112***	-0.492**
	(0.026)	(0.104)	(0.035)	(0.163)			(0.039)	(0.193)
Health (bad health as a base category)								
Good	-0.014	-0.060	-0.037*	-0.148*	-0.051***	-0.215***	0.066***	0.331***
	(0.014)	(0.059)	(0.019)	(0.089)	(0.015)	(0.066)	(0.024)	(0.120)
Very good	0.018	0.074	-0.021	-0.085	-0.027	-0.100	0.157***	0.712***
	(0.021)	(0.084)	(0.021)	(0.098)	(0.024)	(0.102)	(0.027)	(0.136)
Individual income (low income as base category)								
Medium	0.004	0.020	-0.014	-0.069	0.0004	-0.100	0.035*	0.138*
	(0.015)	(0.060)	(0.014)	(0.070)	(0.021)	(0.091)	(0.020)	(0.100)
High	-0.053*	-0.213*	0.059	0.231	-	-	0.025	0.134
	(0.027)	(0.109)	(0.049)	(0.274)			(0.028)	(0.143)
Risk investment (in log)	0.001	0.005	-0.006	-0.035	0.010	0.019	0.082***	0.394***
	(0.004)	(0.018)	(0.018)	(0.084)	(0.015)	(0.061)	(0.025)	(0.130)
Farm size (in log)	0.019**	0.079**	-0.023*	-0.107*	0.0001	0.004	-0.021	-0.139*
	(0.009)	(0.036)	(0.013)	(0.065)	(0.009)	(0.040)	(0.013)	(0.076)
Communist	-0.019	-0.082	0.055***	0.251***	-0.028	-0.110	-0.032	-0.072
	(0.034)	(0.136)	(0.018)	(0.080)	(0.019)	(0.079)	(0.033)	(0.164)
Farmer association	-0.009	-0.036	0.003	0.010	0.115***	0.476***	-0.049	-0.117
	(0.016)	(0.067)	(0.022)	(0.100)	(0.035)	(0.145)	(0.036)	(0.172)
Cooperative	-0.082***	-0.331***	0.007	0.034	-0.051**	-0.218*	-0.008	-0.094
	(0.019)	(0.077)	(0.018)	(0.080)	(0.023)	(0.109)	(0.021)	(0.105)
Organic approval (disagree as base category)								
Unsure	-0.057*	-0.233*	0.058	0.209	-0.188***	-0.763***	0.083**	0.377**
	(0.034)	(0.136)	(0.042)	(0.180)	(0.037)	(0.156)	(0.033)	(0.174)
Agree	0.026	0.103*	0.169***	0.736***	-0.005	-0.017	-0.102***	-0.478***
	(0.018)	(0.075)	(0.038)	(0.175)	(0.016)	(0.075)	(0.024)	(0.120)
Intercept	0.094	-2.101**	0.308	-0.744	1.022***	2.203*	-1.610***	-9.460***
	(0.222)	(0.875)	(0.315)	(1.500)	(0.278)	(1.157)	(0.394)	(1.856)
Observations	400	400	540	540	540	540	540	540
Log (pseudo)-likelihood	315.05	-276.19	185.60	-341.72	373.29	-359.45	66.94	-311.09
Wald $\chi^2(q)$	106.67***	104.93***	217.62***	200.51***	251.93***	228.51***	289.36***	248.77***
q	18	18	20	20	20	20	20	20
Pseudo R^2	-0.059	0.003	-0.742	0.029	-0.325	0.017	2.570	0.053

Note: The dependent variable is the individual investment. No treatment is a base category.
Bootstrapped standard errors are in parentheses with 500 bootstrap replications.
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$.

Figures

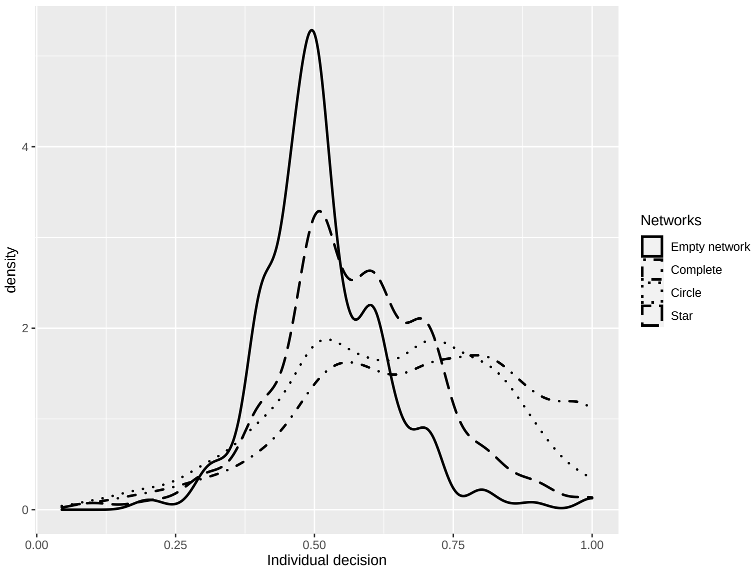


Figure 4.4: Density plot of individual decisions by different networks.

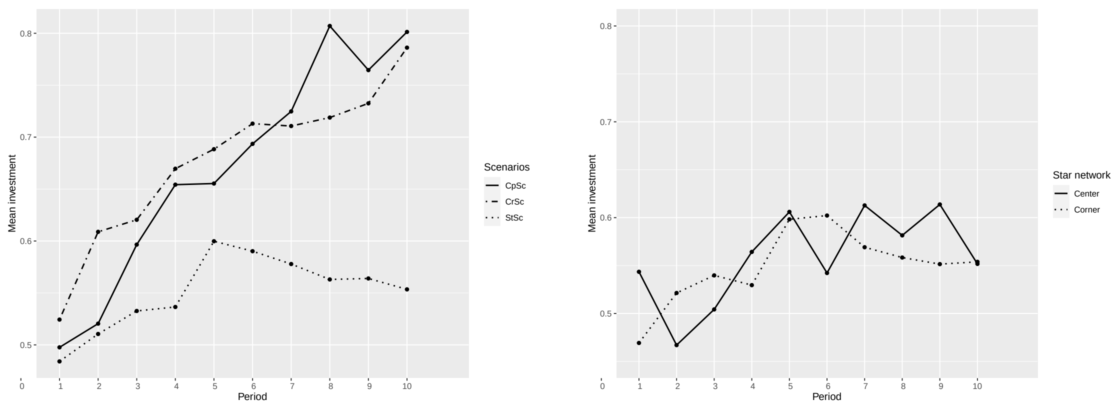


Figure 4.5: Mean investment over time (with social comparison treatments).

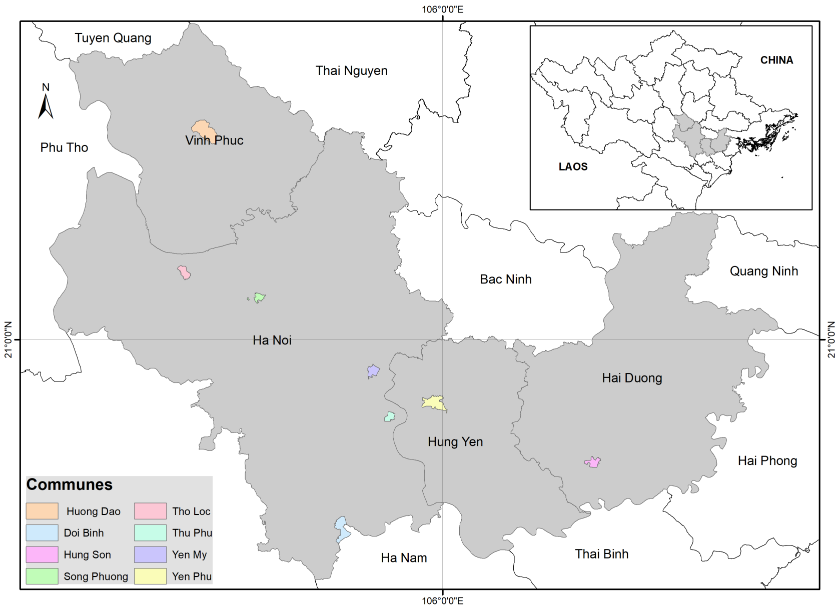


Figure 4.6: The experimental map.

Figure 4.7: The first part of the experiment (lottery-choice task).

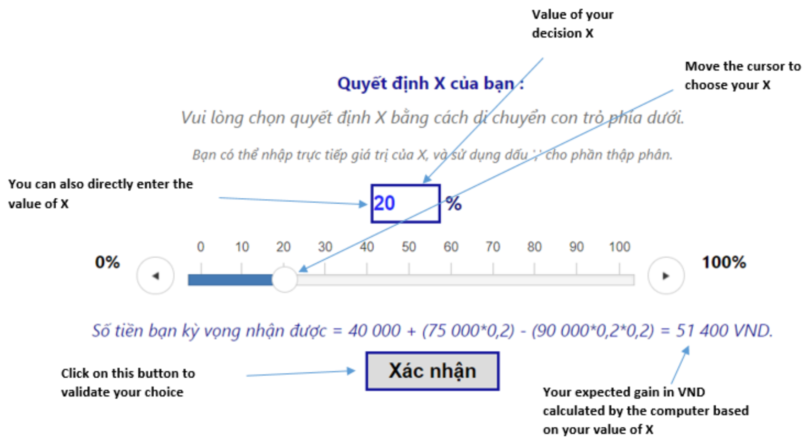


Figure 4.8: The second part of the experiment (simple organic investment game).

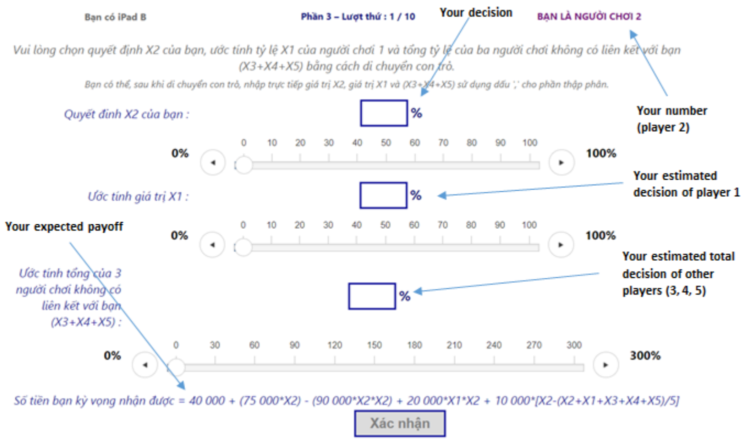


Figure 4.9: The third part of the experiment (an example of the StSc scenario).

Bibliography

Aharoni, R. and P. Haxell (2000). Hall's theorem for hypergraphs. *Journal of Graph Theory 35*(2), 83–88.

Aktar, W., D. Sengupta, and A. Chowdhury (2009). Impact of pesticides use in agriculture: Their benefits and hazards. *Interdisciplinary Toxicology 2*(1), 1–12.

Beaman, L., A. BenYishay, J. Magruder, and A. M. Mobarak (2018). Can network theory-based targeting increase technology adoption? *NBER Working Paper* (24912).

Böhm, R. and B. Rockenbach (2013). The inter-group comparison–intra-group cooperation hypothesis: Comparisons between groups increase efficiency in public goods provision. *PloS One 8*(2), e56152.

Brandon, A., J. A. List, R. D. Metcalfe, M. K. Price, and F. Rundhammer (2019). Testing for crowd out in social nudges: Evidence from a natural field experiment in the market for electricity. *Proceedings of the National Academy of Sciences 116*(12), 5293–5298.

Brick, C., D. K. Sherman, and H. S. Kim (2017). "Green to be seen" and "Brown to keep down": Visibility moderates the effect of identity on pro-environmental behavior. *Journal of Environmental Psychology 51*, 226–238.

Conley, T. G. and C. R. Udry (2010). Learning about a new technology: Pineapple in Ghana. *American Economic Review 100*(1), 35–69.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika 16*(3), 297–334.

Cui, Z., H. Zhang, X. Chen, C. Zhang, W. Ma, C. Huang, W. Zhang, G. Mi, Y. Miao, X. Li, et al. (2018). Pursuing sustainable productivity with millions of smallholder farmers. *Nature 555*, 363–366.

Dessart, F. J., J. Barreiro-Hurlé, and R. van Bavel (2019). Behavioural factors affecting the adoption of sustainable farming practices: A policy-oriented review. *European Review of Agricultural Economics 46*(3), 417–471.

Dunlap, R. E., K. D. Van Liere, A. G. Mertig, and R. E. Jones (2000). New trends in measuring environmental attitudes: Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues 56*(3), 425–442.

Fabregas, R., M. Kremer, and F. Schilbach (2019). Realizing the potential of digital development: The case of agricultural advice. *Science 366*(6471), 1–9.

Fafchamps, M., A. Vaz, and P. C. Vicente (2020). Voting and peer effects: Experimental evidence from Mozambique. *Economic Development and Cultural Change 68*(2), 567–605.

FAO (2017). The Future of Food and Agriculture–Trends and Challenges.

Ferguson, N. (2007). Capturing human behaviour. *Nature 446*(7137), 733–734.

Golub, B. and M. O. Jackson (2010). Naive learning in social networks and the wisdom of crowds. *American Economic Journal: Microeconomics 2*(1), 112–49.

Granovetter, M. (1983). The strength of weak ties: A network theory revisited. *Sociological Theory 1*, 201–233.

Hogset, H. and C. B. Barrett (2010). Social learning, social influence, and projection bias: A caution on inferences based on proxy reporting of peer behavior. *Economic Development and Cultural Change 58*(3), 563–589.

Horrigan, L., R. S. Lawrence, and P. Walker (2002). How sustainable agriculture can address the environmental and human health harms of industrial agriculture. *Environmental Health Perspectives 110*(5), 445–56.

Hotard, M., D. Lawrence, D. D. Laitin, and J. Hainmueller (2019). A low-cost information nudge increases citizenship application rates among low-income immigrants. *Nature Human Behaviour 3*(7), 678–683.

Huang, J., C. Pray, and S. Rozelle (2002). Enhancing the crops to feed the poor. *Nature 418*, 678–684.

Jiang, S. and A. Ngien (2020). The effects of Instagram use, social comparison, and self-esteem on social Anxiety: A survey study in Singapore. *Social Media+ Society 6*(2), 1–10.

Liu, H., J. Meng, W. Bo, D. Cheng, Y. Li, L. Guo, C. Li, Y. Zheng, M. Liu, T. Ning, et al. (2016). Biodiversity management of organic farming enhances agricultural sustainability. *Scientific Reports 6*(1), 1–8.

Mann, H. B. and D. R. Whitney (1947). On a test of whether one of two random variables is stochastically larger than the other. *The Annals of Mathematical Statistics 18*(1), 50–60.

McCubbins, M. D., R. Paturi, and N. Weller (2009). Connected coordination: Network structure and group coordination. *American Politics Research 37*(5), 899–920.

McCullagh, P. (1989). *Generalized Linear Models*. Routledge.

Munasib, A., J. Jordan, et al. (2011). The effect of social capital on the choice to use sustainable agricultural practices. *Journal of Agricultural and Applied Economics 43*(2), 213–227.

Mzoughi, N. (2011). Farmers adoption of integrated crop protection and organic farming: Do moral and social concerns matter? *Ecological Economics 70*(8), 1536–1545.

Papke, L. E. and J. M. Wooldridge (1996). Econometric methods for fractional response variables with an application to 401 (k) plan participation rates. *Journal of Applied Econometrics 11*(6), 619–632.

Ramalho, E. A., J. J. Ramalho, and J. M. Murteira (2011). Alternative estimating and testing empirical strategies for fractional regression models. *Journal of Economic Surveys 25*(1), 19–68.

Reisch, L., U. Eberle, and S. Lorek (2013). Sustainable food consumption: An overview of contemporary issues and policies. *Sustainability: Science, Practice and Policy 9*(2), 7–25.

Rodgers, K. M., J. O. Udesky, R. A. Rudel, and J. G. Brody (2018). Environmental chemicals and breast cancer: An updated review of epidemiological literature informed by biological mechanisms. *Environmental Research 160*, 152–182.

Santos, F. C. and J. M. Pacheco (2011). Risk of collective failure provides an escape from the tragedy of the commons. *Proceedings of the National Academy of Sciences 108*(26), 10421–10425.

Savci, S. (2012). An agricultural pollutant: Chemical fertilizer. *International Journal of Environmental Science and Development 3*(1), 73.

Sudarshan, A. (2017). Nudges in the marketplace: The response of household electricity consumption to information and monetary incentives. *Journal of Economic Behavior & Organization 134*, 320–335.

Urfi, P., K. K. Koch, and Z. Bacsi (2011). Cost and profit analysis of organic and conventional farming in Hungary. *Journal of Central European Agriculture 12*(1), 103–113.

Van Campenhout, B., W. Walukano, F. Nattembo, L. Nazziwa-Nviiri, and J. Blom (2017). The role of Information in agricultural technology adoption: Experimental evidence from rice farmers in Uganda. *IFPRI Discussion Paper Series 01684/2017*, 1–47.

Vandercasteelen, J., M. Dereje, B. Minten, and A. S. Taffesse (2020). From agricultural experiment station to farm: The impact of the promotion of a new technology on farmers' yields in Ethiopia. *Economic Development and Cultural Change 68*(3), 965–1007.

Vogel, E. A., J. P. Rose, B. M. Okdie, K. Eckles, and B. Franz (2015). Who compares and despairs? The effect of social comparison orientation on social media use and its outcomes. *Personality and Individual Differences 86*, 249–256.

West, D. B. et al. (2001). *Introduction to Graph Theory*, Volume 2. Prentice Hall Upper Saddle River.

White, K., R. Habib, and D. J. Hardisty (2019). How to shift consumer behaviors to be more sustainable: A literature review and guiding framework. *Journal of Marketing 83*(3), 22–49.

Wooldridge, J. M. (2009). *Introductory Econometrics: A Modern Approach. 4th*. CENGAGE Learning, Canada.

Chapter 5

Farmers' preferences towards organic farming: Evidence from a choice experiment in Northern Vietnam[1]

5.1 Introduction

In recent years, we have seen a significant increase in organic farming all over the world, up to 11.7 million hectares of organic farming land (i.e., about 20% of agricultural land) worldwide in 2017[2]. Existing literature suggested that organic farming is a more preferable farming technique compared to the conventional farming because organic farmers is less likely to rely on pesticides and chemical fertilizers which could cause extreme soil, water and crop pollution (Bengtsson et al., 2005; Zhengfei et al., 2005). As a result, the less reliance of chemical inputs helps to preserve the soil fertility in the long term. Organic farming could therefore help to produce good quality as well as healthy food for consumers (i.e., increase well-being). Consequently, organic farming will continue expanding worldwide if development and environmental conservation are to be reconciled.

Several developing countries like Vietnam are now in a start-up phase that needs a strong support in its agricultural sector. According to the report of the Vietnamese Ministry of Agriculture and Development, a large proportion of land in Vietnam is dedicated to agriculture (around 40%) and a majority of farmers is smallholder (i.e., about 89%) who

[1]This chapter is based on Boun My K., Nguyen-Quang H., Nguyen-Van P., Pham TKC., Stenger A., Tiet T. and To-The N. (2020), Farmers' preferences towards organic farming: Evidence from a choice experiment in Northern Vietnam. *Submitted*.

[2]The whole report is available at `https://shop.fibl.org/CHfr/mwdownloads/download/link/id/1202/?ref=1`

mainly lives in the rural areas (Rapsomanikis, 2015). This indicates that the primary income source of Vietnamese smallholder farmers comes from agricultural products. However, in one study, the authors have shown that farmers in Vietnam relied heavily on farming inputs, such as pesticides, fertilizers and crop protection inputs (Rapsomanikis, 2015). As a result, in 2017, organic farming in Vietnam represents only about 0.5% of total agricultural land (Willer and Lernoud, 2019).

Existing literature argued that farmers' decisions to adopt or not organic farming are influenced by various monetary and political factors, such as agricultural policy, market configuration and technology design (Darnhofer et al., 2005). In their study, the authors argued that giving compensatory payments within organic farming could motivate farmers to convert their farmlands to organic production for at least five years (Schneeberger et al., 2002; Darnhofer et al., 2005). In addition to these monetary and political drivers as well as social factors (including social influence, norms, nudges, etc.), could also help to influence farmers' decision-making processes (Lynne et al., 1988; Dessart et al., 2019; Streletskaya et al., 2020). Indeed, the role of monetary and social forces is important to promote the adoption of organic farming.

In today world, thanks to the development of online social network platforms, farmers could easily connect to other farmers as well as several online farming organizations/groups. In addition to the online network, most of farmers also belong to some offline networks, such as a network of neighborhood farmers, friends and agricultural organization in the local area (e.g., farmer's association or cooperative, etc.). Hence, networks could be an effective source to diffuse information to farmers and thus help to motivate them to behave positively toward organic farming. For instance, several studies suggested that farmers are more likely to acquire information about dairy farming within their interpersonal social network to enhance their learning and productivity (Sligo and Massey, 2007). Some other studies suggested that frequently communicating/discussing with other neighborhood farmers could significantly help to promote organic farming adoption (Läpple and Van Rensburg, 2011; Unay Gailhard et al., 2015).

Through discrete choice experimental design, our study aims to investigate farmer's preferences as well as their willingness to pay to adopt organic farming. In particular, we aim to provide better understanding about how various market factors (including sale contracts and logo with traceable code) and non-market factors (including role of networks, leaders and training) could drive farmers' decisions toward organic farming, using a discrete choice experiment with 586 farmers in Northern Vietnam. Our results suggest that sale contracts with either flexible or guaranteed prices are a major component explaining farmers' willingness to adopt organic farming. Moreover, "training and technical advice" and "traceability" are also prominent factors that can be used to motivate farmers to move toward organic agriculture. Finally, non-market factors including “neighbor" and “leadership" attributes are also important and need to be taken into account by policymakers and future research because it could help to prioritize between programs targeting on individual farmers or neighborhood networks to effectively promote the pro-environmental behavior change. However, our results suggest that “informal leader" is the only attribute that is statistically significant. This could be because farmers in Vietnamese rural area mainly rely on their formal leaders to receive information as well as to have practical lessons about organic farming.

The remainder of the paper is structured as follows. The background for the study and the literature review are explained in Section 2. Section 3 summarizes our choice experimental design, data collection, and farmers' main characteristics. Section 4 describes the econometric model. Section 5 discusses the main estimation results. Discussion and conclusion are provided in Section 6.

5.2 Background and literature review

5.2.1 Organic farming in Vietnam

Most of Vietnamese farmers are in a conventional farming scheme, in which they highly depend on the use of chemical pesticides and fertilizers. However, this type of farming technique is recognized as unsustainable, even it helps to provide farmers with higher yield as well as higher profit from farming (Berg, 2002). In fact, synthetic substances are easy to be used and require low labor inputs (i.e., labor capital) (Richter et al., 2015). The consequences of synthetic substances are, however, irreversible. For instance, the pesticide overuse tends to increase insect resistance, and thus in the long-run it leads to serious impacts on farmers' as well as consumers' health (Berg and Tam, 2018). Moreover, the surrounding environment could also be seriously threatened (i.e., environmental degradation). Consequently, the negative effects of chemical inputs would lead to reverse impact on the yield, such as decreasing productivity and profit (Berg and Tam, 2018).

In this perspective, Integrated Pest Management (IPM) was introduced as a method for regulating the use as well for management of insect pesticides on the field. Some studies indicated that this method helps farmers to reduce the use of pesticide inputs (Berg, 2002). However, it has been evaluated as being unsuccessful in Vietnam as the use of pesticides has continued to increase in farming practices (Hoi et al., 2016). One study suggested that Vietnamese farmers do not follow the correct practices required for pesticides and fertilizers in the field (Toan et al., 2013). This causes a severe chemical contamination in soil and surface water, especially "ready-to-drink" sources. Thus, people living in the surrounding area, are under the health risk in consuming polluted water (Toan et al., 2013;

Richter et al., 2015). For instance, health problems relating to pesticide and fertilizer exposure have affected around two million Vietnamese farmers (Thai et al., 2017). Vietnamese consumers are more and more concerned about food safety since there were 5,552 case of food poisoning and 23 related deaths in 2015 (World Bank, 2016). However, the government is facing difficulties in managing and regulating those pesticide practices (Van Hoi et al., 2013).

In 1995, Vietnamese government issued "safe vegetable" program to overcome food problem (Mergenthaler et al., 2009; Thai et al., 2017). The objective of this program was to build some safe farming practice and label for vegetable products. However, the quality control and labeling were less reliable and without any standard process (Mergenthaler et al., 2009). As a result, the government introduced a new program which is known as Vietnam Good Agricultural Practices (VietGap) in 2008. VietGap is a Vietnamese standard with a legal regulation system and standardized requirements in agricultural practice, adjusted from Good Agricultural Practices (Chau and Anh, 2015; Thai et al., 2017). A certification is given to farmers who strictly follow the VietGap's guideline. The VietGap scheme has shown some positive impacts on farmer's health and productivity (Chau and Anh, 2015). However, after 10 years of implementation, there are only around 81,500 hectares of farming land allocating to VietGap, representing 0.2 percent of the total agricultural land (Pham et al., 2009; Thai et al., 2017). The reasons are due to some weaknesses in policy implication, unreliable certification process and distrust from consumers (Pham et al., 2009; Thai et al., 2017). Therefore, there is still a need for appropriate agricultural policy.

In 2017, there were around 58,018 hectares for organic agriculture which accounts for 0.5 percent of total agricultural land. This figure is lower than the one in 2015 (76,666 hectares) (Willer and Lernoud, 2019). However, Vietnam is one of the top ten countries with largest organic aquaculture production in the world, with 10800 metric ton in 2016 (Willer and Lernoud, 2019). In term of organic production, in 2016, Vietnam had 10,150 organic producers and the organic agricultural product market develops gradually in Vietnam (Willer and Lernoud, 2019). On the other hand, Vietnamese consumers consider the organic food as healthy and safety so they are willing to pay premium price for organic products (Truong et al., 2012). However, Vietnamese consumers are not familiar with organic food label as well as certification because until recent years, there is no official national organic certification or label (My et al., 2017). As a result, in 2018, Vietnamese government issued an official document for the practices of organic agriculture, which aimed to provide a legal framework and guideline for organic practices (Willer and Lernoud, 2019).

In addition to the national certification, there are also two other available certifying systems in Vietnam: (1) Participatory Guarantee System (PGS) and (2) Third-party certifying organization. On the one hand, the PGS is developed by IFOAM - Organic Internationals certifying system for smallholder farmers. A group of farmers forms a team and commit to the PGS guideline in agricultural production. Every year, the team evaluates each member and certifies that whether members have fulfilled the requirements or not. In Vietnam, there are seven PGS teams that are certified by International Federation of Organic Agriculture Movements (IFOAM - International organization). On the other hand, third-party certifying organization is the certification process for international standards such as USDA in US and EU-Bio in European Community. This certification is however only applied to large-scale Vietnamese farmers or industries.

5.2.2 Discrete choice experiment and organic farming

The discrete choice experiment (DCE) is an experiment based on a repeated individual choice to be done among different hypothetical scenarios which is differentiated by the level of some attributes and the scenario of the status quo. The advantage of this methodology is the possibility to estimate the marginal willingness to pay for each attribute (Chèze et al., 2020). Choice experiment is an appropriate method for conducting research on how different attributes influence farmers' adoption to new technology (Espinosa-Goded et al., 2010; Jaeck and Lifran, 2014; Kwanmuang et al., 2018). The choice experiment model can be used to test whether financial burdens or some labor force prohibit farmers' decisions or not (Kwanmuang et al., 2018). The DCE is also applied to calculate the willingness to pay or the willingness to accept in participating in some agricultural schemes (Schulz et al., 2014; Diederich and Goeschl, 2014). Adoption of organic farming requires farmers to change their habits in using less or even no pesticides and fertilizers. From farmer's perspective, reducing the use of pesticides and fertilizers could increase the risk of productivity loss (Chèze et al., 2020). Therefore, farmers who are willing to adopt organic farming require a certain guarantee in order to compensate the risk.

Several studies suggested that farmers are often uncertain about markets for and prices of the organic products (Jaeck and Lifran, 2014; Van den Broeck et al., 2017). Sale contracts of organic foods (with either flexible or fixed prices) are a solution to overcome the uncertainty of organic agriculture adoption (Greiner, 2016). Payment in terms of additional cost for the adoption is also an important determinants of organic farming adoption (Greiner, 2016; Villanueva et al., 2015). Farmers often have information about the cost of conventional farming, but they are uncertain about the cost of organic farming. Farmers' decisions to adopt organic farming are not only constrained by economics factors but also by non-economic ones. Influence of social acceptance on the adoption of farmers on organic farming is important and needs to be taken into account (Daxini et al., 2018). In their study, the authors found out that Irish farmers observe other farmers' behaviors and then consider the adoption to organic farming or not (Läpple and Kelley, 2013). Based on the Theory of Planned Behavior (Ajzen, 1991), the change in behavior depends partly on farmer's understanding. The knowledge and know-how in adoption to organic farming are also important to them. Farmers also need information and training to adopt organic vegetable (Adebayo and Oladele, 2013). Without proper information, there can be resistance to adoption (Bessette et al., 2019). In the model of new technology adoption, temporal issues can play a role in the sense that some farmers will adopt earlier than others. These farmers are called "opinion leaders". Opinion leaders influence on their followers by giving some information on the quality of adoption (Padel, 2001).

In addition to these important determinants, farmer's socio-demographic characteristics, the size of farming land (i.e., large-scale or smallholder farmers) and farmers' attitudes toward the environment can also help to explain farmers' decisions to adopt organic farming (Padel, 2001; Darnhofer et al., 2005; Läpple and Van Rensburg, 2011; Pilarova et al., 2018). In the study of the determinants of sustainable agriculture adoption in Moldova, the authors concluded that farmers' household characteristics (e.g., age, number of children, number of adults, etc.) and farm size are important factors that influence farmers to adopt the sustainable agriculture (Pilarova et al., 2018). In addition, farmers' awareness and concern about the environment and the consequences from farming activities have positive impacts on the adoption on sustainable agriculture (Zeng et al., 2019).

5.3 Choice experimental design

5.3.1 Attributes

Our choice experiment offers to respondents with multiple choice scenarios. Each time involving a hypothetical situation, farmers were asked to choose one among three options: two "organic farming" alternatives (option 1 and 2) and a "status quo" alternative in which farmers decided to choose neither organic option 1 nor 2. The two alternative "organic" options are described by a number of different attributes.

The selection of attributes in our study is not only based on the literature review, but also discussions with experts in Vietnam. Before the experiment, we conducted a discussion with several experts from agricultural sectors and NGOs. Following the discussion, these experts suggested that two attributes "subsidies for organic farming" and "inspection or control" were discarded based on multiple criteria. Therefore, our study introduces six remaining attributes affecting on the choice of farmers to organic farming: (1) Training and technological advice, (2) Sale contract, (3) Traceability, (4) Neighbor, (5) Leadership, and (6) Additional cost per unit. Each attribute contains different levels for building scenarios.

Table 5.1: Attributes, their levels and experimental design in the choice experiment.

Attributes		Attribute levels
Training and technical advice		Without lesson.[1] With lessons.
Sale contract		No contract.[1] Contract with guaranteed price. Contract with flexible price.
Traceability		Logo without traceability.[1] Logo with traceability.
Neighbor		No neighbor producing organic. Other neighbors producing organic.
Leadership		No leader producing organic.[1] Formal leader producing organic. Informal leader producing organic. Both formal and informal leader producing organic.
Additional cost per unit		0%[1] / 10% / 30% / 60% / 100% / 150%.

Experimental design	
Design approach	Fractional factorial orthogonal design.
Alternatives	Two hypothetical alternatives (option 1 and 2) and one status quo alternative.
Blocks	3 blocks.
Choice tasks	10 choice tasks per block.

Notes: [1] is baseline category.

Our experiment firstly aims to analyze farmers' preferences for organic farming, presented by the first attribute "Training and technical advice". This is defined as practical lessons delivered freely to farmers in order to improve their knowledge about organic farming as well as about organic farming practices. In addition to the "Training", farmers would have technicians or specialists in the local area to help them with technical advice in doing organic farming. Secondly, the sensitivity to different sale contracts in organic farming, presented by the attribute "Sale contract". This is defined as a sale contract between farmers and buyers. The buyers could be the retailers (supermarkets, companies), cooperatives or direct consumers. We would have two different types of contracts: a contract with fixed/guaranteed prices and a contract with flexible prices. Thirdly, the experiment also includes attribute "Traceability", which is a traceable code going along with the organic logo on each organic product. Traceable code on organic products not only helps consumers to easily distinguish between organic products and non-organic ones, but also indicates that farmer's products have already gone through strict quality control. Fourthly, the two last attributes "Neighbor" and "Leadership" indicates that there is the presence of organic neighborhood farmers and leaders in the village. Finally, the "cost" attribute which is a major element using to capture farmers' willingness to pay for organic farming. The cost includes 6 levels which are in terms of percentage increase in production cost, 0%, 10%, 30%, 60%, 100%, 150%. The additional cost per unit is used to capture more accurately farmers' willingness to pay because farmers in different areas often produce different types of agricultural products and even farmers who produce the same type of products may also have a very different production cost. The detailed information about attributes and their levels is reported in Table 5.1.

5.3.2 Experimental design

Our discrete choice experiment is based on a fractional factorial orthogonal design, which contains 30 choice tasks divided in three blocks of 10 choice tasks (Table 5.1). The values of attributes describing the two alternative organic options, varied across every choice task. The choice experiment was conducted through face-to-face IPad-assisted interviews. In particular, respondents were invited to select their favorite farming option among three alternative options (i.e., two alternative organic options and one "status quo") across the different choice tasks. There were several assistants during the experiment to help respondents on the IPad. The experiment started with the definition of organic farming as follows:

> "Organic agriculture is a production method that excludes the use of most chemicals (such as pesticides and fertilizers often used in conventional agriculture since the beginning of the 20th century), GMOs (Genetically Modified Organisms) and crop preservation by irradiation. Organic farming contributes

to reducing environmental impacts (for example, by reducing water pollution and protecting soil fertility, etc.) and improving food quality."

Before delivering the choice card to respondents, each assistant explained to farmers the detailed definition of each attribute. There were two choice card examples giving to farmers to test their understanding of the experiment. Before making their choices, there was an information giving to each farmer as follows:

> “This experiment aims to gain a deeper insight into farmers’ interests in organic farming in the future. In order to do this, in the next step, we will introduce to you several farming scenarios and in each scenario, we invite you to select your most favorite farming management of your agricultural land for the next 5 years. Note that your answers are very important to us, thus we invite you to carefully consider your decisions whether to cultivate and continue to cultivate organic farming or not, based on different assumptions of “training and technical advice", “sale contracts with guaranteed or non-guaranteed prices for 5 years", “product traceability", “organic agricultural production decisions of your neighbors", “organic agricultural production decisions of your leaders, and the cost of organic farming". "

There were totally 10 choice cards, for which each respondent was invited to choose their preferred alternative. There were also two additional choice card, used as examples to test the farmers understanding of the experiment (see Figure 5.1 for an example of the choice card).[3] In each choice card, respondents had to choose one most preferred farming option among two organic farming and one status quo (i.e., “no change" or “I prefer the current farming situation") situation. The status quo option represents the current farming situation, meaning that respondents were not doing organic farming. Totally, 17,580 valid observations were collected from 586 farmers and were used for the empirical analysis.

In addition to the primary experiments, we also collected information from participants on a variety of socio-demographic characteristics. In particular, we collected information on age, gender, farm size, household size, type of residence, individual and household income, health, level of education, marital status, number of children in the household, individual attitudes toward risks, attitudes toward the environment via NEP questionnaires and perception of the adoption of organic farming. The detailed descriptive statistics are presented in next Section.

[3] A Vietnamese version of the choice card is reported in Figure 5.2 in Appendix.

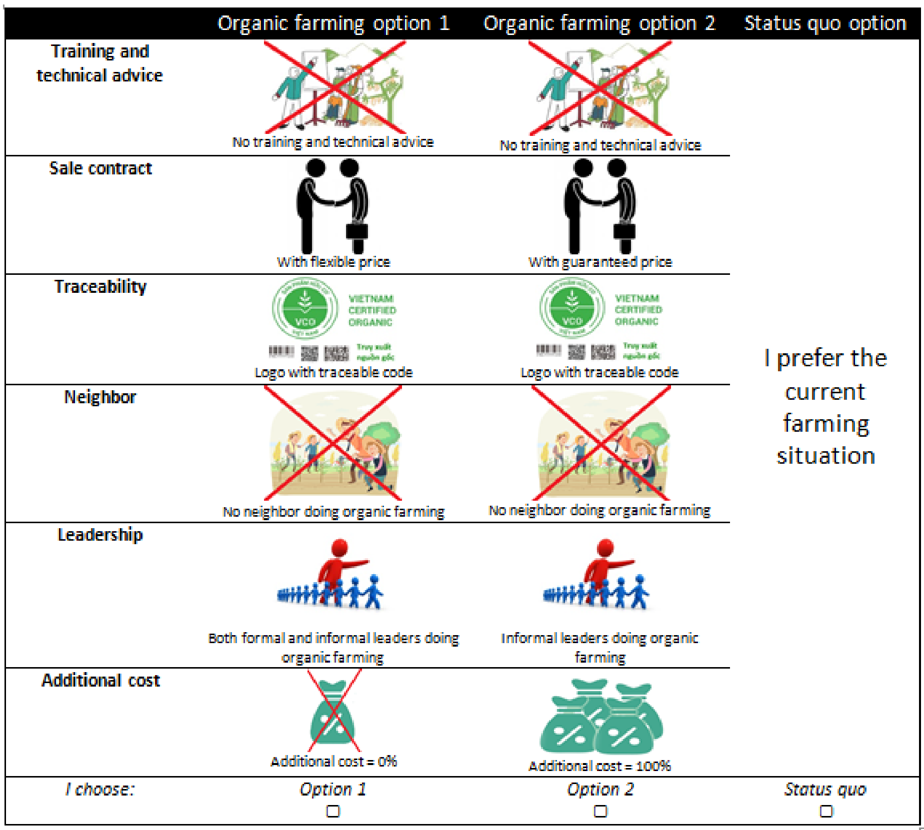


Figure 5.1: Example of choice card (in English).

5.3.3 Data

Our data were collected from a choice experiment, carried out among farmers who were not doing organic farming in 31 different villages in Northern Vietnam. The data collection was conducted in August 2019 with 8 villages, in November 2019 with 11 villages and from December 2019 to January 2020 with 12 villages. There were totally 596 farmers, participated in the choice experiment (see the map of the experimental areas in Figure 5.3 in the Appendix). However, we finally obtain only 586 valid survey answers in total. There were 10 invalid observations removed from the dataset because of missing information about the respondent's current production cost. Note that the current production cost is an important element, which is required for calculating the "cost" attribute and estimating the willingness to pay. The experiments were conducted with farmers in the village using IPad. There were several assistants in the field to help farmers to use the IPad.

The experiment consists of four different parts. The first part of the experiment includes some warm-up questions, which is designed to obtain information about farmers' current farming situations and their situations in past related to organic farming. The second part addresses to the choice experiment, which includes 12 choice cards. Note that the first two choice cards were used as examples for respondents to better understand the choice experiment. The third part of the experiment is designed to obtain information about farmers' production activities (e.g., main agricultural products, production cost, etc.). The last part is designed to obtain information about farmers' socio-demographic characteristics, their lifestyles and attitudes toward the environment and perception of organic farming. In addition to farmers' socio-demographic characteristics, we also elicit information on a number of environmental concerns via 15 NEP questionnaires to help us identify farmers' perceptions of the environment (see the details of the NEP questionnaires in Table 5.7 in Appendix) (Dunlap et al., 2000). There are also several questions related to environmental concerns asked in order to capture farmers' opinions, attitudes and concerns toward the environment. All questionnaires will be available in Supplementary Materials. Detailed summary statistics are reported in Table 5.2.

5.4 Econometric model

In this section, we briefly discuss about how Random Parameter Logit (RPL) and Hybrid Choice Model (HCM) structures are applied to study farmer's preferences towards organic farming (McFadden, 1973; Ben-Akiva et al., 2002; Bolduc and Alvarez-Daziano, 2010; Anastasopoulos and Mannering, 2011). In a standard Random Utility Model (McFadden, 1973; Hensher, 1982), we consider that the individual i's utility function for alternative n in choice task t is given by:

$$U_{i,n,t} = V_{i,n,t} + \epsilon_{i,n,t}, \tag{5.1}$$

where, $V_{i,n,t}$ is the deterministic component of i for alternative n in choice task t and $\epsilon_{i,n,t}$ is the error component (i.e., random component) of the utility function.

Let $x_{i,n,t}$ be a set of observable attributes of the alternative n and z_i be a set of respondent i's socio-economic characteristics (e.g., income, age, education, etc.). In a traditional model, we have $V_{i,n,t} = f(x_{i,n,t}, z_i, \beta)$ with $f(.)$ be a linear-in-attribute specification. The two organic farming option $V_{i,n,t}$ for $n = \{1, 2\}$ are written as follows:

$$V_{i,n,t} = \mu_{ASC} ASC_{i,n,t} + \beta_c(\pi_i + \pi_i c_{i,n,t}) + \sum_{l=1}^{L} \beta_l Attribute_{i,l,n,t} + \sum_{s=1}^{S} \gamma_s ASC_{i,n,t} * Control_{i,s}. \tag{5.2}$$

It should be noted that our experiment is the unlabeled choice experiment (i.e., the two organic alternatives are unlabeled). In order to capture the unobserved influences on the utility function, let's $ASC_{i,n,t}$ be the Alternative Specific Constant which is a dummy variable taking value 1 if the organic alternatives are chosen. Thus, parameter μ_{ASC} be the Alternative Specific Constant, which is a coefficient of the dummy variable $ASC_{i,n,t}$. The control variables $Control_s$ including a set of S socio-economic variables (e.g., farmer's characteristics, individual income, etc.). π_i is the unit cost of farmer i associated with the current production. $c_{i,n,t}$ is the levels of additional costs of alternative n farming compared to the current production. $\pi_i c_{i,n,t}$ is farmer i's additional costs relative to the adoption of alternative n. $\pi_i + \pi_i c_{i,n,t}$ is then the total cost of adopting alternative n organic farming. $Attribute_l$ is a set of L attributes including training and technical advice, sale contract, traceability, neighbor, and leadership.

The utility function of choosing the status quo is denoted $V_{i,3,t}$ (i.e., $n = 3$ represented for the status quo) can be written as follows:

$$V_{i,3,t} = \mu_0 + \beta_c \pi_i. \tag{5.3}$$

Random Parameter Logit Model

Following the existing literature, we assume that the errors are independently and identically distributed with an extreme-value, leading to a logistic form for the probability of choosing alternative j (Hynes et al., 2005; Anastasopoulos and Mannering, 2011). However, differently from the literature, as the unit cost was collected after the choice sets in our experiment, there are three ways to estimate the model. Firstly, we directly estimate (5.2) by using a conditional logit (CL) model based on total costs $\pi_i + \pi_i c_{i,n,t}$, other attributes, and the ASC indicator. This regression gives estimates for $\mu_{ASC}, \beta_c, \beta_l, \gamma_s$. Secondly, there could be some inconsistency or error in the amount of declared production costs π_i, as well as heterogeneity in individual preferences that could influence respondents' decisions. Consequently, our estimation should account for this by rewriting Equation (5.2) as follows:

$$V_{i,n,t} = \mu_{ASC} ASC_{i,n,t} + \tilde{\beta}_c(\pi_i + \pi_i c_{i,n,t}) + \sum_{l=1}^{L} \tilde{\beta}_l Attribute_{i,l,n,t} + \sum_{s=1}^{S} \gamma_s ASC_{i,n,t} * Control_{i,s}. \tag{5.4}$$

This corresponds to a model with parameter heterogeneity (or random parameter) associated to attribute variables. Its estimation requires an additional assumption about this heterogeneity, i.e.

$$\tilde{\beta}_c = \bar{\beta}_c + \eta_c \tag{5.5}$$

$$\tilde{\beta}_l = \bar{\beta}_l + \vartheta_l \tag{5.6}$$

with $\eta_c \simeq \mathcal{N}(0, \sigma^2_{\beta_c})$ and $(\eta_c, \vartheta_l)' \simeq \mathcal{N}(0, \Omega)$, where Ω is the variance-covariance matrix of dimensions $K + 1$ (which is the total number of levels in the attributes). The random parameter logistic (RPL) regression gives estimates for $\bar{\beta}_c$, $\bar{\beta}_l$, μ_n and γ.

Hybrid Choice Model

We consider that respondents' decisions in adoption of organic farming are also influenced by their concerns about the environment (i.e., attitudes towards the environment) in Table 5.7 and perceptions of the adoption of organic farming in Table 5.3. Let I_i be a set of respondent i's attitudes towards and perceptions of the adoption of organic farming (i.e., indicators of respondent i's attitudes and perceptions). Existing literature indicated that the simple inclusion of I_i in $V_{i,n,t}$ is theoretically misguided and could lead to problems with measurement error because questions about attitudes, concerns and perceptions are not direct measures of such attitudes, concerns and perceptions (Ben-Akiva et al., 2002; Bolduc and Alvarez-Daziano, 2010). Another reason is because of the risk of endogeneity bias since there is likely to be correlation between I_i and other unobserved factors $\epsilon_{i,n,t}$ influencing respondent i's behavior.

Hybrid Choice Model (HCM) is an approach, developed to deal with these problems by seeing I_i as a dependent variable rather than an explanatory variable. In particular, in the HCM model, we hypothesize that the true underlying individual attitudes, concerns and perceptions are described as a set of k unobserved latent variables, namely $LV_{i,k}$. These latent variables (LVs) could influence respondents' responses to the attitudinal and perceptional questions, as well as drive respondents' behaviors in the actual choice situations. More specially, we have the latent variables for respondent i (i.e., structural equation for latent variable) that are given by:

$$LV_{i,k} = \sum_{s}^{S} \gamma_{LV_k,s} z_{i,s} + \xi_{i,k}, \tag{5.7}$$

where, $z_{i,s}$ is a set of S socio-demographic variables of respondent i (e.g., age, gender, income, etc.) (all of the control variables are reported in Table 5.2), γ_{LV_k} is k vector of estimated parameters capturing the impacts of socio-demographic variables on $LV_{i,k}$ and ξ_k is a random disturbance which follows a standard Normal distribution across individuals, $\xi_k \simeq \mathcal{N}(0,1)$. In our model, we include two latent variables (including environmental concerns and perceptions of the adoption of organic farming), described by several attitudinal and perceptional indicators (see Table 5.7 for 15-NEP questions and Table 5.3 for four perceptional questions).

As previously discussed, the latent variables $LV_{i,k}$ are also used to explain the values of the indicators of attitudes and perceptions for respondent i (i.e., the measurement component for the indicators).

$$I_{i,k} = \eta_{I_k} + h(LV_{i,k}, \zeta_{I_k}) + \psi_{I_{i,k}}, \tag{5.8}$$

where, the functional form $h()$ is left to the analyst to decide, but generally, a linear specification is used, η is a vector of constant, ζ is a vector of estimated parameters showing the impact of the k latent variables on various indicators and ψ is a random disturbance. Since the indicators $I_{i,k}$ are categorical variables (i.e., 5-Point-Likert scale items), Equation (5.8) can be estimated using ordinal regression (i.e., Ordered Logit Model) to capture the discrete-ordered nature of the items (Daly et al., 2012). The likelihood of the observed sequence of answers to the attitudinal and perceptional questions, $L_{I_{i,k}}$, can be written as follows:

$$L_{I_{i,k}}(\zeta_{I_k}, \tau_{I_k}, LV_{i,k}) = \prod_{I_k} \left(\frac{e^{\tau_{j,I_k} - \zeta_{I_k} LV_{i,k}}}{1 + e^{\tau_{j,I_k} - \zeta_{I_k} LV_{i,k}}} - \frac{e^{\tau_{j-1,I_k} - \zeta_{I_k} LV_{i,k}}}{1 + e^{\tau_{j-1,I_k} - \zeta_{I_k} LV_{i,k}}} \right), \tag{5.9}$$

where, τ is a vector of threshold parameters for the indicators in the Ordered Logit Model.

In addition to the measurement component, we also have the choice model component, where the latent variables are incorporated into the utility specification. Specially, we have the utility function as follows:

$$\begin{aligned} V_{i,n,t} = {} & (\mu_{ASC} + \lambda_k LV_{i,k}) ASC_{i,n,t} + \tilde{\beta}_c(\pi_i + \pi_i c_{i,n,t}) + \sum_{l=1}^{L} \beta_l Attribute_{i,l,n,t} \\ & + \sum_{s=1}^{S} \gamma_s ASC_{i,n,t} * Control_{i,s}, \end{aligned} \tag{5.10}$$

where, λ is a vector of estimated parameters measuring the impact of the k latent variables on respondent's utility. In particular, we would have the likelihood of observed sequence of T_i choices for person i as follows:

$$L_{C_i}(\beta_i, \gamma_i, LV_{i,k}) = \prod_{t=1}^{T_i} \frac{e^{V_{i,n,t}}}{\sum_{j=1}^{3} e^{V_{i,j,t}}}, \tag{5.11}$$

where, β_i and γ_i are groups of random and deterministic components, respectively.

Consequently, the Hybrid Choice Model is made of two key components including measurement components and choice model components. Both of these components depend on the latent variables $LV_{i,k}$, which are estimated simultaneously. It should be noted that sequential estimation is possible, but it could result in a loss of efficiency. Thus, we have the combined log-likelihood as follows:

$$LL(\Omega) = \sum_{i=1}^{N} log \int_{\beta_i} \int_{LV_{i,k}} L_{C_i}(\beta_i, \gamma_i, LV_{i,k}) L_{I_{i,k}}(\zeta, \tau, LV_{i,k}) f(\beta_i) g(LV_{i,k}) d\beta_i dLV_{i,k}, \quad (5.12)$$

where, $\Omega = \{\mu, \beta, \gamma_s, \gamma_{LV}, \zeta, \lambda\}$ combines all model parameters; L_{C_i} is the likelihood of observed sequence of choices for person i; $L_{I_{i,k}}$ is the likelihood of the observed sequence of answers to the k attitudinal and perceptional questions. The Log-likelihood requires the integration over the distribution of β_i and α_i and thus this explains the presence of the density function $f(\beta_i)$ and $g(LV_{i,k})$.

Willingness to pay estimates

When estimates for parameters of the model are available, we can calculate the marginal willingness to pay (WTP) for each of the attributes to pass from the state 3 (i.e., status quo) to the alternative n (i.e., two alternative organic option $n = \{1, 2\}$) (Hanemann, 1984; Hanley et al., 2001). We have the marginal WTP estimate is given by:

$$WTP = -\frac{1}{\beta_c} log \left[\frac{\sum_i exp(V_{i3})}{\sum_i exp(V_{in})} \right], \quad (5.13)$$

where, β_c is the coefficient of the cost attribute.

In traditional model, β_c which is directly obtained by the regression based on total cost variable. In reporting the willingness to pay for attribute n (i.e., WTP_n), the log expression in Equation (5.14) simplifies to the coefficient of this attribute, giving $WTP_n = -\beta_n/\beta_c$.

However, when the random parameter associated to the k attributes $\tilde{\beta}_k$ for $k = \{n, c\}$, assumed to be log-normal distributed, we can estimate the WTP of the n attribute by

$$WTP_n = -\frac{\tilde{\beta}_n}{\tilde{\beta}_c} = -\frac{exp(b_n)}{exp(b_c)}, \quad (5.14)$$

where, $\tilde{\beta}_k \simeq exp(b_k)$ and $b_k \simeq N(\mu_k, \sigma_k^2)$ (Meijer and Rouwendal, 2006). Thus, WTP_n is lognormally distributed, $WTP_n \simeq LN(\tilde{\mu}_n, \tilde{\sigma}_n^2)$, where $\tilde{\mu}_n = \mu_n - \mu_c$ and $\tilde{\sigma}_n^2 = \sigma_n^2 + \sigma_c^2$. For any $k = \{n, c\}$, the mean μ_k and standard deviation σ_k can be estimated from the random-coefficient model. From the mean and the standard deviation of the lognormally distributed WTP_n, one can calculate the mean, median and standard deviation of the WTP values (i.e., WTP space) (Hole, 2008; Train, 2009). Moreover, when the random parameter associated to the k attributes $\tilde{\beta}_k$ for $k = \{n, c\}$, are normally distributed ($N(0, \sigma_k^2)$), we can simply calculate the mean WTP by $E(WTP_n) = -\bar{\beta}_n/\bar{\beta}_c$ (see Equations (5.5) and (5.6) for the assumptions about the parameter heterogeneity).

5.5 Estimation results

5.5.1 Descriptive statistics

The descriptive statistics of socio-economic characteristics, individuals' concerns about the environmental and their perceptions of adoption of organic farming are presented in Table 5.2. The socio-economic control variables include: *Types of agricultural products* include three dummy variables (*Rice*, *Vegetables*, and *Others*) that take a value of 1 if farmers mainly produced rice, vegetables and other types of products, respectively; *Female*, a dummy that takes a value of 1 if the farmer is female; *Age* is the log of individual age; *Education* is a category variable that takes the value of 1, 2 or 3 if the individual level of education is below secondary school (grade 6 to grade 9), or below vocational school (1 to 2 years after high school), or college and university; *Health* is a category variable that takes the value of 1, 2 or 3 if the individual has bad health, good health or very good health, respectively; *Income* is a category variable that takes a value 1 if the individual is in the low income group (monthly earnings $<$ 4 million VND), a value of 2 if the individual is in the middle income group (monthly earnings from 4 to 8 million VND) and a value of 3 if the individual is in the high income group (monthly earnings $>$ 8 million VND); *Farmsize* is the log of household farmer's farming land (in m^2).

In addition to the socio-demographic control variables, the psychological control variables include: *NEP score* is the aggregate score of individual 15 New Environmental Paradigm questions (Table 5.7 in the Appendix) and *Perception score* is the aggregate score of four items related to farmers' perceptions of the adoption of organic farming in Table 5.3. Total NEP score is the aggregate score of 15 NEP questions (in Table 5.7 in the Appendix), in which the Cronbach alpha is equal to 79.02% and the questions number 2, 4, 6, 8, 10, 12 and 14 (even number questions) are reversely coded (Cronbach, 1951). While, the *NEP score* variable is used to capture respondents' environmental concern, the *Perception score* measures respondents' perceptions of the adoption of organic farming, which is an aggregate score calculated using four 5-Point-Likert scale items (see Table 5.3).

According the statistics reported in Table 5.2, a majority of farmers in our sample produced rices (45.39%) and vegetables (33.62%). The rest of farmers produced fruits, corns and other types of agricultural products. The average production cost over three different types of agricultural products was about 5,843 VND/kg.[4] Farmers were, on average, 51 years old, ranging from 18 to 74 years old. There were 66% of female farmers in our sample. A majority of the farmers in the sample was smallholder farmers with the average farm size of 4,221 m^2. Farmer's education level is mainly below high school, with only 6% of them graduated from college or university. About 78% of farmers in our study indicated

[4]equivalent to about 0.25 USD/kg.

that they had a good health. Most of farmers belonged to the low income group since their monthly income was a below 4 million VND[5]. Only 7% of farmers told us that they had a high monthly income, which is higher than 8 million VND/month.

Table 5.2: Summary statistics of survey respondents (N=586)

	Mean	Std.Dev	Min	Max
Types of agricultural products				
Rice	0.45	0.49	0	1
Vegetables	0.33	0.47	0	1
Others	0.21	0.40	0	1
Production cost (VND/kg)	5,843.81	4,316.78	500	46,723
Female	0.66	0.47	0	1
Age (yrs)	51.30	11.67	18	74
Age (in log)	3.90	0.25	2.89	4.30
Education				
High school	0.27	0.44	0	1
College/University	0.06	0.23	0	1
Health				
Good	0.78	0.41	0	1
Very good	0.17	0.37	0	1
Individual income				
Middle	0.29	0.45	0	1
High	0.07	0.25	0	1
Farm size (m^2)	4,221.17	7,035.40	50	70,000
Farm size (in log)	7.79	0.96	3.91	11.15
NEP score	47.60	4.63	35	64
Perception score	15.1	2.35	4	20

Notes: Other agricultural products include fruits, coins and other types of products.

According to our hypotheses discussed in previous section (see Equation (5.8) for the measure model component), we define two latent constructs ($LV_{Concern}$ and $LV_{Perception}$) which are measured by two sets of indicators, $I_{i,k}$. The first set of of 5-Point-Likert scale items measures the respondents' concerns about the environment ($LV_{Concern}$) (i.e., respondents' awareness about the environment), covering the 15 NEP questions in Table 5.7. The second set of 5-Point-Likert scale items is used to capture respondents' perceptions of the adoption of organic farming (e.g., does the adoption of organic farming approve by other

[5] equivalent to about 167 USD/month.

villagers, etc.). The four indicators used for the perception of the adoption of organic farming are listed in Table 5.3.

For consistency with the choice model, we use the same socio-demographic characteristics for the structural estimation of the two latent variables. In other words, we apply a same set of $control_{i,s}$ presented in Equation (5.10) to $z_{i,s}$ presented in Equation (5.7), but we exclude the two variables including *NEP score* and *Perception score* since in the Hybrid Choice Model, we have to separately estimate respondents' concerns and perceptions in the measurement model component (see Equation (5.8)). The separate identification of the parameters associated with the same characteristics (i.e., the parameters of $control_{i,s}$ and $z_{i,s}$) is ensured by the fact that for one of them, the value is driven by both the choice data and the indicator variables.

Table 5.3: Descriptive statistics of perceptional variables (in percentage).

Item	Description	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
Perceptions of organic farming						
$Perception1$	Food safety problem was seriously caused by abuse of pesticides and fertilizers in farming.	3.58	6.83	1.37	57.00	31.23
$Perception2$	It is useful for farmers to adopt organic farming to protect the environment and population health.	2.39	0.68	1.37	66.21	29.35
$Perception3$	Adopting organic farming practices is common in the village.	7.85	23.04	14.85	46.76	7.51
$Perception4$	Most other villagers approve of adopting organic farming practices during the production.	2.39	9.56	20.99	58.02	9.04
Total Perception score		Mean = 15.1 and SD = 2.35. Cronbach's alpha = 0.51				

5.5.2 Results

Our results are first estimated using the Conditional Logit (CL) and Random Parameter Logit (RPL) models. Estimation results for the CL and RPL models are reported in Table 5.4. In Table 5.4, Models (CL 1) and (CL 2) correspond to the utility function in Equation (5.2), which is estimated by the Conditional Logit with and without control variables.

While Model (CL 1) is estimated without any control variable, Model (CL 2) is estimated by taking farmers' socio-demographic control variables into account. Because of identification issue (i.e., respondent's characteristics do not vary across choices), only interaction terms between these control variables and the ASC (i.e., Alternative Specific Constant) can be estimated. The ASC, which is code as a dummy taking a value of 1 if farmers preferred the "organic farming" options to the "status quo". Hence, the estimation with relevant interaction terms are presented in Model (CL 2), such as their interactions (Female, Age, Farm size, Income, Education, Health, NEP score, Perception score and types of agricultural products) with ASC. The Likelihood ratio test of Model (CL 1) and (CL 2) suggest that Model (CL 2) with interaction terms is preferable with $\chi^2(13) = 174.89$ and $p < 0.001$. Therefore, further econometric analysis should involve the model with interactions.

The three columns (RPL 1), (RPL 2) and (RPL 3) in Table 5.4 report the results of the Random Parameter Logit (RPL) model. Model (RPL 1) corresponds to the model specified by the utility function (5.4) and the heterogeneity in the "cost" attribute (5.5). Model (RPL 2) is similar to Model (RPL 1), but we take respondents' socio-demographical variables into account. Model (RPL 3) corresponds to the model, where the coefficients of all of the attributes and the ASC include the random heterogeneity. We observe that the standard deviations of majority of the attributes are statistically significant, except for the "Traceability", "Neighbor" and "Leadership". This indicates that the RPL model controlling for the heterogeneity of "ASC", "Cost", "Training" and "Sale contract" attributes, provides a significantly better representation of choices than the conditional logit model in capturing heterogeneity among respondents. The Likelihood ratio (LR) test of Models (RPL 3) and (RPL 2) is equal to $\chi^2(8) = 21.674$ with $p = 0.005$. This suggests that the full Random Parameter Logit model with interaction terms (RPL 3) is preferable. The LR test also indicates that Model (RPL 2) is preferred to Models (RPL 1), which suggests that the model with interactions is preferred to the one without interactions (the test statistics is also reported in Table 5.4).

Table 5.4: Summary results of the Conditional and Random Parameter Logit models.

Variable	Conditional Logit		Random Parameter Logit		
	CL 1	CL 1	RPL 1	RPL 2	RPL 3
Mean estimation					
ASC	-0.723***	-4.506***	4.913***	-9.919***	-15.275***
	(0.089)	(0.849)	(1.702)	(3.329)	(5.372)
Training and technical advice	0.685***	0.690***	0.894***	0.890***	1.350***
	(0.043)	(0.043)	(0.064)	(0.063)	(0.221)
Sale contract					
With guaranteed price	1.003***	1.010***	1.405***	1.385***	2.089***
	(0.049)	(0.050)	(0.092)	(0.087)	(0.335)
With flexible price	0.963***	0.966***	1.085***	1.096***	1.529***
	(0.060)	(0.060)	(0.088)	(0.086)	(0.223)
Traceability	0.489***	0.493***	0.620***	0.615***	0.943***
	(0.044)	(0.044)	(0.070)	(0.068)	(0.175)
Neighbor	0.212***	0.218***	0.474***	0.457***	0.715***
	(0.045)	(0.045)	(0.080)	(0.076)	(0.155)
Leadership					
Formal leader	0.664***	0.662***	0.449***	0.473***	0.572***
	(0.075)	(0.075)	(0.129)	(0.123)	(0.183)
Informal leader	0.409***	0.407***	0.205	0.224*	0.154
	(0.078)	(0.079)	(0.138)	(0.132)	(0.219)
Both leaders	0.422***	0.423***	0.478***	0.472***	0.551***
	(0.063)	(0.068)	(0.103)	(0.100)	(0.154)
Cost	-0.103***	-0.106***	-0.360***	-0.340***	-0.492***
	(0.006)	(0.006)	(0.042)	(0.038)	(0.093)
Std.Dev estimation					
ASC			7.790***	6.115***	9.810***
			(1.911)	(1.178)	(2.337)
Cost			0.428***	0.395***	0.565***
			(0.062)	(0.056)	(0.120)
Training and technical advice					1.605***
					(0.444)
Sale contract					
With guaranteed price					1.449***
					(0.538)
With flexible price					0.908**
					(0.436)
Traceability					0.197
					(0.416)
Neighbor					0.097
					(0.312)
Leadership					
Formal leader					0.512
					(0.383)
Informal leader					1.021
					(0.852)
Both leaders					1.102***
					(0.421)
Mean estimation of interaction terms					
ASC*Age		0.918***		2.908***	4.438***
		(0.141)		(0.701)	(1.170)
ASC*Middle income		-0.171**		-0.500*	1.046**
		(0.082)		(0.303)	(0.526)
ASC*Good health		-0.538***		-1.631**	-2.351**
		(0.204)		(0.702)	(1.033)
ASC*Very good health		-0.584***		-1.861**	-2.609**
		(0.219)		(0.775)	(1.148)
ASC*High school		0.163*		0.669**	-1.588*
		(0.085)		(0.324)	(0.944)
ASC*Perception score		0.061***		0.216***	0.338***
		(0.014)		(0.069)	(0.120)
ASC*Rice		0.547***		2.181***	3.578***
		(0.091)		(0.504)	(1.009)
ASC*Vegetables		0.412***		1.645***	2.752***
		(0.096)		(0.453)	(0.863)
Observations	17,580	17,580	17,580	17,580	17,580
Log likelihood	-5380.95	-5293.38	-5266.7	-5185	-5174.3
LR χ^2(q)	(2114, q=10)	(2289, q=23)	(2149.01 q=2)	(2007.45, q=2)	(2133.21, q=10)
p-value	< 0.001	< 0.001	< 0.001	< 0.001	< 0.001

Note: Standard error in parenthesis. ASC stands for Alternative Specific Constant.
Control variables including *Female*, *Farm size*, *High income*, *College/University*, *NEP score* and *Concern score*, are significant at the 10% level.
LR test of RPL 1 and RPL 2: $\chi^2(13) = 163.34$ with $p < 0.001$. LR test of RPL 3 and RPL 2: $\chi^2(8) = 0.005$ with $p = 0.005$.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

The results of both CL and RPL models suggest that the coefficients of all attributes are statistically significant and have expected sign (i.e., only cost attribute has negative sign, while the sign of other attributes are positive), expect for the "Informal leader" attribute. Thus, farmers appreciate providing training and technical advice, supporting sale contract, providing logo with traceable code (e.g., QR code), encouraging their neighbor's organic farming, as well as formal and both leaders' organic farming to promote organic agriculture. As expected, the cost attribute coefficient has a negatively significant impact on farmers' decisions which indicates that higher cost has a negative effect on respondent's utility. The results of Table 5.4 also suggest that ASC (i.e., Alternative Specific Constant) is negative and significant after controlling for both the random and deterministic heterogeneity (see Model (RPL 3) in Table 5.4). The coefficient of the ASC is negative and statistically significant at 1% level, meaning that farmers in our experiment valued positively the fact of staying in the "status quo" situation (i.e., farmers prefer the "status quo" to the organic farming).

Hybrid Choice Model

In addition to the CL and RPL models, the Hybrid Choice Model (HCM) is presented in order to enrich the underlying behavioral characterizations with the explicit modeling of latent psychological variables (i.e., respondents' concerns about the environment and their perceptions of the adoption of organic farming) (Ben-Akiva et al., 2002; Bolduc and Alvarez-Daziano, 2010). The estimation results of the HCM model (HCM 1) with one latent variable "Perception" ($LV_{Perception}$) are reported in Table 5.5, while Table 5.9 (in the Appendix) presents the results of the Hybrid Choice Model (HCM 2) with two latent variables "Perception" ($LV_{Perception}$) and "Concern" ($LV_{Concern}$). The results are obtained using simulation-based approach with 500 Halton draws to ensure the stability of the presented results. Note that a more number of Halton draws is required in order to obtain a stable estimation result. However, a too high number of draws could increase drastically the estimation time because of the high number of observations, several different latent variables, and a large number of random parameters.

The first part of the results in Tables 5.5 and 5.9 (in the Appendix) shows the estimation of the choice model component, which is estimated using the combined log-likelihood in Equation 5.12, allowing the heterogeneity of ASC and all of the attributes as previously discussed in the RPL model (i.e., mixed logit estimation). The choice model is estimated with the same set of control variables as in the CL and RPL models, except for the two concern and perceptional score variables since we will estimate them separately in the measurement component model. The right hand side of Table 5.5 and Table 5.9 (in the Appendix) represents the results of the coefficients (γ) of the structural equation of the LVs defined in Equation (5.7) using the same set of control variables as in the choice model.

The coefficients of the LVs (ζ) of the measurement component for the four indicators and the threshold parameters (τ) (i.e., four threshold parameters per indicator should be estimation since we have 5-Point-scale dependent variable) are estimated using the Ordered Logit Model, which are reported in the last part of Table 5.5. Note that in the case of the presence of two latent variables, the coefficients (ζ) and threshold parameters (τ) of each LV on 19 indicators (i.e., 15 NEP and four perceptional indicators) should be estimated. The results are reported in Table 5.9 in the Appendix.

A comparison of Tables 5.4 and 5.5 leads to the following conclusions. The result of the HCM confirms that the ASC has a negative and statistically significant impact on respondents' choices. It suggests that farmers generally seem to be less willing to move towards organic farming (i.e., they prefer the "status quo" to the organic farming options). We find that the major reason that Vietnamese farmers do not prefer "status quo" alternative, is not because they are not interested in organic farming, but because there is lack of subsidies and information related to organic agriculture. From our follow-up survey, we observe that there were total about 7% of farmers always choosing the "status quo" option. A majority of these farmers said that they do not prefer organic farming alternatives because they believe that there is no neighbor doing organic farming (37.21%), lack of sufficient information related to organic farming (34.88%), lack of subsidies from the government (27.91%), and it is too difficult to market organic products (25.58%).

The estimates of the coefficients of the attributes in the Model (HCM 1) are more or less close to the results of the RPL model. We observe that all attributes are positive and statistically significant, while the "cost" attribute has a negative and significant impact of respondents' choices, as we expected. However, the results of both Tables 5.4 and 5.5 confirm that the "Informal leader" is the only attribute which is not statistically significant at the 10% level. The "Informal leader" attribute is defined as the presence of informal leaders (e.g., religious leaders or the most successful farmers in the village, etc.) in the village who is doing organic farming. This means that the presence of organic informal leaders could not significantly influence farmers to behave positively toward organic farming. While informal leaders have no significant effect on organic farming adoption, the presence of formal and of both leaders play important role in promoting organic farming. It should be noted that, unlikely people living in the cities, people who live in the Vietnamese rural areas often have close ties/connections, not only to their informal leaders but also to the formal leaders. However, farmers in the rural areas in Vietnam often rely on their formal leaders (e.g., village leaders or a president of farmer's association, etc.) to obtain information, knowledge as well as practical lessons about organic farming. As a result, they prefer to have either formal leaders or both formal and informal leaders in their villages to motivate them to move towards organic farming (Pielstick, 2000; Sleeth-Keppler et al., 2017).

Table 5.5: Summary results of the Hybrid Choice Model with "Perception" latent variable.

	HCM 1				
Variable	Coef.	Variable	Coef.	Variable	Coef.
Choice model component		**Socio-demographic variables on LV "*Perception*"**		**LV "Perception" on its indicators**	
ASC	-9.965**	$\gamma_{Perception,Female}$	0.145	$\zeta_{Perception,1}$	1.192***
	(5.171)		(0.125)		(0.371)
Training and technical advice	1.008***	$\gamma_{Perception,Age}$	0.743***	$\tau_{Perception,11}$	0.997
	(0.075)		(0.252)	$\tau_{Perception,12}$	2.234
Sale contract with fixed price	1.546***	$\gamma_{Perception,FarmSize}$	0.103**	$\tau_{Perception,13}$	2.386
	(0.101)		(0.049)	$\tau_{Perception,14}$	5.825
Sale contract with flexible price	1.223***	$\gamma_{Perception,MiddleIncome}$	0.122	$\zeta_{Perception,2}$	2.905***
	(0.095)		(0.138)		(0.659)
Traceability	0.662***	$\gamma_{Perception,HighIncome}$	0.110	$\tau_{Perception,21}$	5.196
	(0.077)		(0.314)	$\tau_{Perception,22}$	5.560
Neighbor	0.441***	$\gamma_{Perception,GoodHealth}$	-0.045	$\tau_{Perception,23}$	6.119
	(0.065)		(0.411)	$\tau_{Perception,24}$	13.622
Formal leader	0.516***	$\gamma_{Perception,VeryGoodHealth}$	-0.090	$\zeta_{Perception,3}$	0.599***
	(0.116)		(0.459)		(0.220)
Informal leader	0.177	$\gamma_{Perception,HighSchool}$	0.444***	$\tau_{Perception,31}$	-0.184
	(0.124)		(0.156)	$\tau_{Perception,32}$	1.522
Both leaders	0.414***	$\gamma_{Perception,College}$	0.914***	$\tau_{Perception,33}$	2.193
	(0.098)		(0.344)	$\tau_{Perception,34}$	5.065
Cost	-0.335***	$\gamma_{Perception,Rice}$	-0.030	$\zeta_{Perception,4}$	1.181***
	(0.028)		(0.160)		(0.369)
$\lambda_{LV_{Perception}}$	0.762***	$\gamma_{Perception,Vegetable}$	-0.160	$\tau_{Perception,41}$	0.519
	(0.183)		(0.175)	$\tau_{Perception,42}$	2.383
Std.Dev estimation					
ASC	-3.355***			$\tau_{Perception,43}$	3.879
	(0.373)			$\tau_{Perception,44}$	7.618
Training and technical advice	0.640***				
	(0.126)				
Sale contract with fixed price	0.969***				
	(0.102)				
Sale contract with flexible price	0.532***				
	(0.211)				
Traceability	0.753***				
	(0.102)				
Neighbor	-0.307**				
	(0.153)				
Formal leader	0.231				
	(0.385)				
Informal leader	0.510**				
	(0.217)				
Both leader	-0.021				
	(0.240)				
Cost	0.310***				
	(0.032)				
Estimation of interaction terms					
ASC*Age	2.483***				
	(0.452)				
Observations	17,580	LL of the combined model	-6683.49	AIC	13492.99
Estimation time	08h:09m:43s	LL of the choice model	-4224.97	BIC	13913.57
Number of parameters	63				

Note: Estimation performed on an 8 cores and 100Gb ram computers.
Results of Model (HCM 2) with two latent variables "Concern" and "Perception" are reported in Table 5.9 in the Appendix.
Robust standard errors in parenthesis. ASC stands for Alternative Specific Constant.
Control variables of the Choice model, including *Female*, *Farm size*, *Income*, *Education*, *Health* and *Types of agricultural products*, are not reported since they are not statistically significant at the 10% level.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

In addition to the "leadership" attribute, the "neighbor" attribute, which is defined as the presence of neighborhood farmers in the village doing organic farming, has a positive and statically significant impact on farmers' decisions in adoption of organic farming. This indicates that network of farmers (e.g., neighbors or friends) could play an important role in promoting organic farming. This is because farmers living in the rural areas often interact frequently with their neighbors/friends as they always live nearby and thus, they know really well each other (i.e., they have strong connections with their neighbors). This result is in line with the existing literature since individual-to-individual links are important and valuable of sources of information, knowledge as well as thoughts for individuals that could help to significantly motivate people to behave positively towards pro-environmental behaviors (Olli et al., 2001; Jackson, 2010; Axsen et al., 2013; Lazaric et al., 2019).

Regarding the effect of the latent variables on farmers' choice, we observe that the coefficient $\lambda_{LV_{Perception}}$ is positive and statistically significant in Table 5.5 and 5.9 (in the Appendix), while the coefficient $\lambda_{LV_{Concern}}$ is statistically significant (see Table 5.9 in the Appendix). This suggests that individuals who have stronger perception of adoption of organic farming (e.g., they believe that "it is useful for farmers to adopt organic farming to protect the environment and population health), will be more likely to choose the organic farming alternatives than others who do not. This confirms our prior expectations. However, we observe that the coefficients $\zeta_{Perception}$ (including $\zeta_{Perception,1}$, $\zeta_{Perception,2}$, $\zeta_{Perception,3}$ and $\zeta_{Perception,4}$, which represent for the impacts of the LV "Perception" on four perceptional indicators listed in Table 5.3) are positive and significant, which suggest that a higher value of the latent variable corresponds to stronger perception of organic farming. Our results suggest that the model with only "Perception" latent variable could give us better interpretation of respondents' choices since the effect of the LV "Concern" ($\lambda_{LV_{Concern}}$) is not significant and the HCM model with two LVs (HCM 2) provide a poor estimation results in the measurement model component (see Table 5.9).

Since the socio-demographic and -economic variables do not change over choice cases, we interact them with the ASC. In Model (HCM 1) in Table 5.5, we observe that a majority of coefficients of the interaction terms is not statistically significant, including, "Female", "Farm size", "Education", "Income", "Health" and "Types of agricultural products". This means that these socio-demographic characteristics could not significantly influence farmers' decisions in adopting organic farming. However, we observe that older farmers are more and more aware of health risk and are more about their future generations (e.g., children and grand-children), thus they seem to be more likely to adopt organic agriculture than the younger. We observe also that older farmers have stronger perception of adoption of organic farming than the younger since the coefficient $\gamma_{Perception,Age}$ is positive and significant (see column 2 of Table 5.5). Larger scale farmers (i.e., larger farm size) seem to have stronger perception of organic farming than smaller scale ones (i.e., $\gamma_{Perception,FarmSize}$

is positive and significant) and thus they are more likely to choose the organic farming alternative. This is because large scale farmers are often more able to approach the organic farming technique other smallholder ones. Farmers who graduated from high school and college, are willing to behave positively toward organic farming compared to others. This reveals that farmers with better education have stronger perception of adoption of organic farming, are more concern about the problem of conventional agriculture than others and thus they are more willing to change their farming method to organic farming.

Estimation of willingness to pay

Table 5.6 reports the calculation of the mean Willingness to Pay (WTP) for all the attribute levels, using three different Models (RPL 3), (HCM 1) and (HCM 2). In the result, we also look at the differences in WTP in different types of agricultural products (i.e., rice, vegetables and other products). We observe that the results of the WTP estimates are very close in these three models, especially between Models (HCM 1) and (HCM 2). There is no WTP of the “Informal leader" attribute since its coefficient estimate is not statistically significant at the 10% level. As a result, in HCM Model, we estimate only the WTP for the case of all products because of costly computational estimation cost for estimating several time the HCM model and also because we would expect to have the similar results to the ones of the random parameter logit model (RPL 3).

According to the result in Model (HCM 1), we observe that farmers are willing to pay on average 3.00 thousand VND/kg to get practical lessons about organic farming and to have technicians or specialists in the village or in the field to advise them in doing organic farming. Farmers seem to be willing to pay more to obtain the sale contract with buyers or retailers (e.g., industries, supermarkets, direct consumers, etc.), about 4.60 and 3.64 thousand VND/kg for sale contract with guaranteed prices and flexible prices, respectively. Farmers seem to prefer the contract with fixed/guaranteed prices (i.e., product prices are fixed over 5 years) to the one with flexible prices (i.e., product prices float by market prices). The farmers are willing to pay on average 1.97 thousand VND/kg to get a organic logo with traceable code on their products. The “neighbor" and “leadership" attribute are also important since farmers are also willing to pay to have farmers and leaders in their village doing organic farming.

Table 5.6: Estimated willingness to pay (WTP) for the attribute levels.

	HCM 1	HCM 2	RPL 3			
Attributes	All products	All products	All products	Rice	Vegetables	Others
Training and technical advice	3.00	2.97	2.74	2.21	4.52	3.27
	[2.69,3.31]	[1.49,4.44]	[2.11,3.36]	[1.86,2.55]	[2.49,6.56]	[2.38,4.17]
Sale contract						
With guaranteed prices	4.60	4.58	4.24	2.82	8.15	5.75
	[4.18,5.03]	[3.10,6.05]	[3.45,5.02]	[2.43,3.22]	[5.43,10.87]	[4.80,6.69]
With flexible prices	3.64	3.60	3.10	1.69	6.24	4.13
	[3.24,4.05]	[1.48,6.05]	[2.24,3.96]	[1.35,2.03]	[3.09,9.39]	[3.15,5.11]
Traceability	1.97	1.91	1.91	1.13	2.99	2.88
	[1.69,2.25]	[0.86,2.96]	[1.34,2.48]	[0.84,1.42]	[1.45,4.52]	[1.92,3.83]
Neighbor	1.31	1.27	1.45	1.37	1.87	1.78
	[1.10,1.52]	[1.05,1.50]	[0.99,1.90]	[1.02,1.73]	[0.79,2.95]	[0.89,2.68]
Leadership						
Formal leader	1.54	1.58	1.16	0.96	1.79	-
	[1.15,1.93]	[0.79,2.54]	[0.30,2.01]	[0.65,1.28]	[0.59,4.17]	
Informal leader	-	-	-	-	-	-
					-	
Both leaders	1.23	1.30	1.11	0.75	-	1.55
	[0.90,1.55]	[0.59,1.96]	[0.44,1.79]	[0.33,1.17]		[0.49,2.61]

Note: WTP are in thousand VND/unit.
Confidence interval (CI) at 5% significant level. Standard deviation is calculated by the delta method (for the detail of computation, see the paper of Hole (2007)).
Model (HCM 1) is the Hybrid Choice Model with one LV variable "Perception". Model (HCM 2) is the Hybrid Choice Model with two LV variables "Perception" and "Concern".
The WTP estimates are calculated from the results of Models (HCM 1), (HCM 2) and (RPL 3) which are the model with socio-demographic and psychological control variables. The "All products" is the model with all three types of agricultural products.
There is no WTP estimate for the "Informal leader" attribute because their coefficient estimates are not statistically significant.

The estimated willingness to pay are of significant importance to policymakers. Relative importance of the attributes can be derived from the values of their WTP, whereby those with higher WTPs are assigned more resources than the others. In this study, the WTP of sale contract including contracts with guaranteed prices and with flexible prices are consistently higher than other attributes. This reflects the fact that farmers involved in organic farming, highly value the sale contract with buyers or retailers to ensure that their products can be sold to the market with either flexible or fixed prices. This is consistent with intuition as guaranteed product prices and outcomes is very important because majority of farmers in our study are smallholder farmers. The existing literature argued that smallholder farmers in Vietnam strongly depend on traders to sell their products, but traders are the ones who set the price and farmers have to accept the price offered to them (Minot, 2006).

Looking at the results in different types of agricultural products (including rice, vegetables and other products), our results indicate that farmers generally have a positive WTP for organic farming. Farmers who produce mainly vegetables seem to be willing to pay more to change their farming method to organic farming than others who produce mainly rice. This could be because it is often more costly for vegetable producers to invest in organic farming than rice producers because of the high production cost per kilogram (kg) of vegetable products (i.e., production price per kg is often higher in vegetables than rice). Moreover, all types of producers seem to be willing to pay to more to have sale contracts with flexible prices, but less to have neighbors doing organic farming. These results are intuitive because sale contract directly links to the profit or revenue of the organic farming which is one of the major barriers to organic farming adoption (Schneeberger et al., 2002; Läpple and Kelley, 2013). The organic neighbors otherwise do not have direct link to the income from farming, but neighbors could help each other by sharing recommendations, advice, knowledge as well as important alerts during the implementation of organic farming, which are also important for maintaining a long-run sustainable behavior (Genius et al., 2006; Hall and Rhoades, 2010).

It should be noted that the WTP is calculated when both parameters (i.e., β_n and β_c see Equation (5.14)) used in calculation are statistically significant, otherwise no meaningful WTP measure can be established. For this reason, there is no WTP estimate for either only informal leadership or only formal leadership attributes in case that farmers producing mainly other type of products (e.g., fruit, corn, etc.). We observe that "formal leader" attribute only has a significant impact on the willingness to pay for organic farming of rice and vegetable producers. However, vegetable producers does not seem to be willing to pay to have both their formal and informal leaders doing organic farming. In other words, only farmers who produced rice are willing to pay to have leaders (either formal or informal) in the local area doing organic farming. This could be because organic rice farming is often more difficult to be accessed and takes longer to cultivate, and more importantly organic rice has limited demand and inadequate marketing (i.e., more difficult to market organic rice), compared to organic vegetables or other type of products (Chouichom et al., 2010; Mishra et al., 2018). Consequently, smallholder rice producers are willing to pay to have leaders who are also doing organic farming in their village, and thus the leaders could help not only to share their knowledge and practical lessons to local farmers, but also to provide them information to market their crops.

5.6 Discussion and conclusion

This paper aims to investigate farmers' preferences to adopt organic farming. We use a quantitative approach based on discrete choice experiment with 586 farmers in Northern Vietnam to measure how various factors could influence farmers' decisions in adopting organic farming. We value farmers' willingness to pay for both market and non-market components of their decisions such as practical training lessons and technical advice in the local area, sale contract with guaranteed or flexible price with retailers (e.g., direct consumers, supermarkets, industries, etc.), organic logo with traceable code, the presence of neighbors and leaders in their village doing organic farming.

Our results suggest that all above mentioned attributes have significant impacts on farmers' decisions to adopt organic farming. Firstly, we find that sale contracts with either flexible or guaranteed prices are major components explaining farmers' willingness to adopt organic farming. This is because a majority of farmers in our study are smallholders, who always experience more difficulties to market their crops, and thus the agricultural product outcome commitment from buyers is seen by them as an opportunity for supporting organic agriculture. This result is in line with the literature of "contract farming" (i.e., purchaser provides farmers credit, technical advice, market service, etc. In return, farmers produce certain quantity and quality products and sell them to purchaser), indicating that such arrangement could contribute positively to farmers' revenue in particular as well as to growth and poverty reduction in general (Weiss and Khan, 2006; Bolwig et al., 2009).

Secondly, the "traceability" attribute is also an important factor that help to encourage the adoption of organic farming. In fact, it is often required for farmers who would like to obtain a sale contract to have logo with traceable code because it indicates that the organic products have go through strict quality controls as well as production monitory systems. Thus, our result suggests that farmers are willing to pay on average 1.97 thousand VND/kg for obtaining traceable code. Additionally, consumers are always more likely to pay higher prices for higher quality foods, and thus logo with traceable code could also help them to distinguish the good quality organic foods from the low quality ones. As a result, traceability stands as the best tool for food quality control as well as for encouraging consumer confidence in organic products that will be consumed (Wu et al., 2011; Spence et al., 2018).

Thirdly, in addition to the market factors, training and technical advice is a prominent non-market factor that can be used to motivate farmers to move toward organic agriculture. All else being equal, farmers are willing to pay 3.00 thousand VND/kg to get practical training lessons and technicians or specialists in local area for technical assistance. This amount will be much higher (4.52 thousand VND/kg) for farmers who produce mainly vegetables compared to other types of agricultural products. This result is straightforward because several existing study suggests that technical knowledge of organic farming practices is one important barrier to organic transition (Brock and Barham, 2013; Dimitri and Baron, 2019). Therefore, providing training and technical assistance to farmers is really important to motivate the adoption of organic farming.

Fourthly, the "neighbor" attribute is also important to encourage farmers to change their farming method to organic farming. More importantly, our results shed light on the role of neighborhood organic farming on farmers' decisions since we observe that farmers are willing to pay 1.31 thousand VND/kg to have farmers in their neighborhood doing organic farming. This suggests that the presence of neighborhood farmers doing organic farming plays an important role in promoting the organic agriculture in the region like Northern Vietnam. Existing literature also indicated that programs targeting whole community are more effective than targeting individual farmers to induce behavioral changes (Nyblom et al., 2003; Wollni and Andersson, 2014; Läpple and Kelley, 2015). In their study, the authors argued that individual farmers are less likely to apply the organic practice that helps to restore soil function because they fear that their neighborhood farmers may free-ride on their investments into soil and fertility improvements, unless all farmers in the neighborhood commit this organic practice (Wollni and Andersson, 2014). Therefore, the role of networks (i.e., neighborhood farmers doing organic farming) is also important and need to be taken into account by policymakers because it could help to prioritize between programs targeting on individual farmers or neighborhood networks to effectively promote the pro-environmental behavior change.

Finally, our results find that farmers' willingness to pay are very different across different types of agricultural products (e.g., rice, vegetables, fruits, corns, etc.). For instance, organic vegetable farmers are willing to pay more than rice or other types of producers, but rice producers are the only ones, willing to pay to have formal leaders as well as both formal and informal leaders in their village doing organic farming. This is not only because of differences in unit cost of different types of products, but because organic farmings of some types of agricultural products (like rice) are more difficult to market compared to organic vegetables or other type of products. Therefore, further research is still needed to establish the actual costs and benefits of organic farming adoption by taking the different types of agricultural products into account in this research area. The complementary cost-benefit analysis can additionally provide policymakers with other benefits that may be caused by long-term reduction of pesticide uses and the uses of other harmful plant protection products. The long-run discount rate should also be considered because the organic farming investment has welfare effects for future generations.

Tables

Table 5.7: The 15 NEP scale items and their response distributions (in percentage).

NEP scale items	Strongly disagree	Partly dis-agree	Unsure	Partly agree	Strongly agree	Corr
1:"We are approaching the limit of the number of people the earth can support".	6.14	24.74	17.06	40.96	11.09	0.471
2:"Humans have the right to modify the natural environment to suit their needs".[a]	7.68	15.87	6.83	55.46	14.16	0.477
3:"When humans interfere with nature it often produces disastrous consequences".	9.73	31.40	10.24	38.74	9.90	0.469
4:"Human ingenuity will ensure that we do not make the earth unlivable".[a]	5.63	9.22	8.70	63.82	12.63	0.557
5:"Humans are severely abusing the environment".	7.68	21.33	4.10	48.12	18.77	0.542
6:"The Earth has plenty of natural resources if we just learn how to develop them".[a]	4.44	2.22	4.44	71.50	17.41	0.617
7:"Plants and animals have as much right as humans to exist".	3.75	7.00	4.78	65.87	18.60	0.611
8:"The balance of nature is strong enough to cope with the impacts of modern industrial nations".[a]	11.09	39.25	16.55	28.16	4.95	0.316
9:"Despite our special abilities, humans are still subject to the laws of nature".	3.75	3.92	1.88	70.31	20.14	0.556
10:"The so-called "ecological crisis" facing humankind has been greatly exaggerated".[a]	9.56	43.34	18.09	25.94	3.07	0.381
11:"The Earth is like a spaceship with very limited room and resources".	3.41	6.14	8.02	67.58	14.85	0.571
12:"Humans were meant to rule over the rest of nature".[a]	5.63	23.04	16.04	46.76	8.53	0.505
13:"The balance of nature is very delicate and easily upset".	3.24	12.46	12.80	63.14	8.36	0.524
14:"Humans will eventually learn enough about how nature works to be able to control it".[a]	3.58	18.60	9.22	59.56	9.04	0.535
15:"If things continue on their present course, we will soon experience a major ecological catastrophe".	3.58	6.31	7.00	64.16	18.94	0.570
Total NEP score		Mean = 47.60 and SD = 4.62. Cronbach's alpha = 0.7902				

Notes: [a] Reverse coded.
The column Corr represents the item-test correlation, which tells us how much each items correlates with the total NEP score. The Cronbach's alpha equals to 79.02 % in the reliability test, which suggests that 79.02% of the variance in the score is reliable.

Table 5.8: Correlation matrix of nine indicators of the "Concern" and "Perception" latent variables (with Pearson's correlation test).

	Concern 1	Concern 2	Concern 3	Concern 4	Concern 5	Perception 1	Perception 2	Perception 3	Perception 4
Concern 1	1.00								
Concern 2	-0.20	1.00							
	(0.00)								
Concern 3	0.28	-0.04	1.00						
	(0.00)	(0.00)							
Concern 4	-0.13	0.31	-0.19	1.00					
	(0.00)	(0.00)	(0.00)						
Concern 5	0.25	-0.09	0.42	-0.28	1.00				
	(0.00)	(0.00)	(0.00)	(0.00)					
Perception 1	0.17	-0.06	0.13	-0.11	0.21	1.00			
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)				
Perception 2	0.15	-0.11	0.11	-0.21	0.16	0.40	1.00		
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)			
Perception 3	0.06	-0.06	-0.02	-0.07	0.00	-0.03	0.16	1.00	
	(0.00)	(0.00)	(0.02)	(0.00)	(0.60)	(0.00)	(0.00)		
Perception 4	0.07	-0.05	0.00	-0.16	0.04	0.11	0.33	0.40	1.00
	(0.00)	(0.00)	(0.54)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	

Notes: The *p*-value of the Pearson correlation test statistics are in parentheses.
The Pearson correlation test statistics suggest that the correlation between the indicators of the two latent variables exist. However, the correlation coefficients of these indicators are not too large (i.e., a majority of the correlation coefficients is below 0.20).

Table 5.9: Summary results of the Hybrid Choice Model with “Concern" and “Perception" latent variables.

	HCM 2				
Variable	Coef.	Variable	Coef.	Variable	Coef.
Choice model component		**Socio-demographic variables on LV “*Concern*"**		**LV “Concern" on its indicators**	
ASC	-11.019***	$\gamma_{Concern,Female}$	0.014	$\zeta_{Concern,1}$	0.861
	(3.170)		(0.382)		(0.701)
Training and technical advice	0.984***	$\gamma_{Concern,Age}$	0.653	$\zeta_{Concern,2}$	-1.139*
	(0.232)		(1.132)		(0.601)
Sale contract with fixed price	1.517***	$\gamma_{Concern,FarmSize}$	0.102	$\zeta_{Concern,3}$	0.817*
	(0.148)		(0.178)		(0.431)
Sale contract with flexible price	1.193***	$\gamma_{Concern,MiddleIncome}$	-0.049	$\zeta_{Concern,4}$	-1.591
	(0.379)		(0.243)		(1.027)
Traceability	0.633***	$\gamma_{Concern,HighIncome}$	-0.174	$\zeta_{Concern,5}$	1.211***
	(0.182)		(0.848)		(0.390)
Neighbor	0.422***	$\gamma_{Concern,GoodHealth}$	-0.198	$\zeta_{Concern,6}$	-1.894***
	(0.129)		(1.554)		(0.282)
Formal leader	0.525***	$\gamma_{Concern,VeryGoodHealth}$	0.048	$\zeta_{Concern,7}$	1.832***
	(0.137)		(1.651)		(0.654)
Informal leader	0.223	$\gamma_{Concern,HighSchool}$	0.083	$\zeta_{Concern,8}$	-0.218
	(0.166)		(0.740)		(0.346)
Both leaders	0.431***	$\gamma_{Concern,College}$	0.356	$\zeta_{Concern,9}$	1.419
	(0.106)		(1.007)		(0.912)
Cost	-0.331***	$\gamma_{Concern,Rice}$	-0.131	$\zeta_{Concern,10}$	-0.454
	(0.093)		(0.920)		(0.373)
$\lambda_{LV_{Concern}}$	-0.070	$\gamma_{Concern,Vegetable}$	-0.440	$\zeta_{Concern,11}$	1.490*
	(0.876)		(0.615)		(0.855)
$\lambda_{LV_{Perception}}$	3.076***			$\zeta_{Concern,12}$	-1.094**
	(0.968)	**Socio-demographic variables on LV “*Perception*"**			(0.536)
Std.Dev estimation					
ASC	0.509	$\gamma_{Perception,Female}$	0.354	$\zeta_{Concern,13}$	1.438***
	(1.114)		(0.611)		(0.506)
Training and technical advice	-0.602**	$\gamma_{Perception,Age}$	2.523***	$\zeta_{Concern,14}$	-1.464***
	(0.311)		(0.997)		(0.198)
Sale contract with fixed price	0.973***	$\gamma_{Perception,FarmSize}$	0.275	$\zeta_{Concern,15}$	1.796***
	(0.146)		(1.079)		(0.607)
Sale contract with flexible price	-0.457	$\gamma_{Perception,MiddleIncome}$	0.513		
	(1.098)		(2.020)	**LV “Perception" on its indicators**	
Traceability	0.654*	$\gamma_{Perception,HighIncome}$	0.700	$\zeta_{Perception,1}$	0.265
	(0.428)		(0.698)		(0.343)
Neighbor	0.043	$\gamma_{Perception,GoodHealth}$	0.102	$\zeta_{Perception,2}$	0.400
	(0.611)		(1.209)		(0.440)
Formal leader	-0.345	$\gamma_{Perception,VeryGoodHealth}$	0.012	$\zeta_{Perception,3}$	0.224
	(0.881)		(0.642)		(0.181)
Informal leader	-0.161	$\gamma_{Perception,HighSchool}$	1.557	$\zeta_{Perception,4}$	0.308
	(4.035)		(1.235)		(0.382)
Both leader	-0.299	$\gamma_{Perception,College}$	2.821***		
	(0.703)		(1.073)		
Cost	0.317***	$\gamma_{Perception,Rice}$	-0.014		
	(0.080)		(1.237)		
Estimation of interaction terms					
ASC*Age	-5.367***	$\gamma_{Perception,Vegetable}$	-0.194		
	(1.795)		(0.648)		
ASC*Middle income	-2.280				
	(3.183)				
ASC*High income	-2.893**				
	(1.473)				
ASC*High school	-4.681***				
	(1.769)				
ASC*College	-9.018***				
	(1.222)				
Observations	17,580	LL of the combined model	-16649.41	AIC	33598.81
Estimation time	115h:00m:30s	LL of the choice model	-4229.32	BIC	34600.2
Number of parameters	150				

Note: Estimation performed on an 4 cores and 8Gb ram computers.
Robust standard errors in parenthesis. ASC stands for Alternative Specific Constant.
Threshold parameters τ of the measurement component of LV “Concern" and LV “Perception" are estimated, but they are reported.
Control variables: *Female*, *Farm size*, *Health* and *Types of agricultural products* of the Choice model, including *Rice*, *Vegetables* and *Others*, are not reported since they are not statistically significant at the 10% level.
* $p < 0.1$; ** $p < 0.05$; *** $p < 0.01$.

Figures

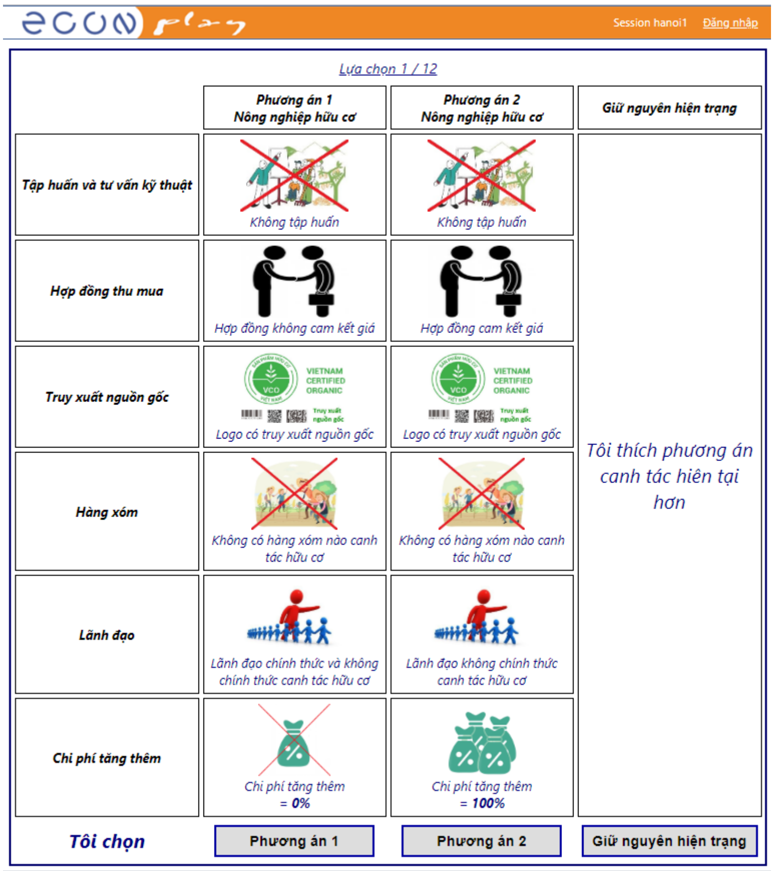


Figure 5.2: Example of choice card (in Vietnamese).

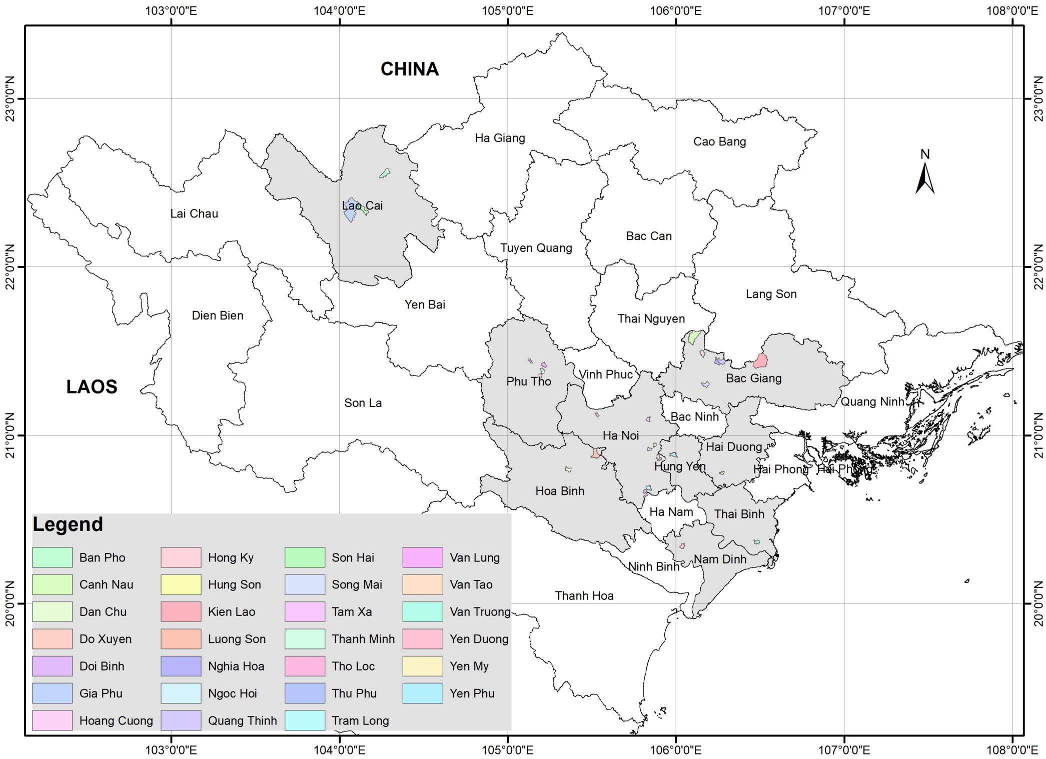


Figure 5.3: Experimental areas.

Bibliography

Adebayo, S. A. and O. I. Oladele (2013). Vegetable farmers' attitude towards organic agriculture practices in South Western Nigeria. *Journal of Food, Agriculture and Environment 11*(2), 548–552.

Ajzen, I. (1991). The theory of planned behavior. *Organizational Behavior and Human Decision Process 50*, 179–211.

Anastasopoulos, P. C. and F. L. Mannering (2011). An empirical assessment of fixed and random parameter logit models using crash-and non-crash-specific injury data. *Accident Analysis & Prevention 43*(3), 1140–1147.

Axsen, J., C. Orlebar, and S. Skippon (2013). Social influence and consumer preference formation for pro-environmental technology: The case of a UK workplace electric-vehicle study. *Ecological Economics 95*, 96–107.

Ben-Akiva, M., D. McFadden, K. Train, J. Walker, C. Bhat, M. Bierlaire, D. Bolduc, A. Boersch-Supan, D. Brownstone, D. S. Bunch, et al. (2002). Hybrid choice models: Progress and challenges. *Marketing Letters 13*(3), 163–175.

Bengtsson, J., J. Ahnström, and A.-C. WEIBULL (2005). The effects of organic agriculture on biodiversity and abundance: A meta-analysis. *Journal of Applied Ecology 42*(2), 261–269.

Berg, H. (2002). Rice monoculture and integrated rice-fish farming in the Mekong Delta, Vietnam - Economic and ecological considerations. *Ecological Economics 41*(1), 95–107.

Berg, H. and N. T. Tam (2018). Decreased use of pesticides for increased yields of rice and fish-options for sustainable food production in the Mekong Delta. *Science of the Total Environment 619*, 319–327.

Bessette, D., S. Zwickle, and R. Wilson (2019). In the weeds: Distinguishing organic farmers who want information about ecological weed management from those who need it. *Renewable Agriculture and Food Systems 34*(5), 460–471.

Bolduc, D. and R. Alvarez-Daziano (2010). On estimation of hybrid choice models. In *Choice Modelling: The State-of-the-art and The State-of-Practice*. Emerald Group Publishing Limited.

Bolwig, S., P. Gibbon, and S. Jones (2009). The economics of smallholder organic contract farming in tropical Africa. *World Development 37*(6), 1094–1104.

Brock, C. C. and B. L. Barham (2013). 'Milk is milk': Organic dairy adoption decisions and bounded rationality. *Sustainability 5*(12), 5416–5441.

Chau, T. H. B. and L. T. Q. Anh (2015). Impact of VietGAP vegetable production on the health of farmers in Thua Thien Hue province, Vietnam. Technical Report rr2015101, Economy and Environment Program for Southeast Asia (EEPSEA).

Chèze, B., M. David, and V. Martinet (2020). Understanding farmers' reluctance to reduce pesticide use: A choice experiment. *Ecological Economics 167*, 106349.

Chouichom, S., M. Yamao, et al. (2010). Comparing opinions and attitudes of organic and non-organic farmers towards organic rice farming system in north-eastern thailand. *Journal of Organic Systems 5*(1), 25–35.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika 16*(3), 297–334.

Daly, A., S. Hess, B. Patruni, D. Potoglou, and C. Rohr (2012). Using ordered attitudinal indicators in a latent variable choice model: A study of the impact of security on rail travel behaviour. *Transportation 39*(2), 267–297.

Darnhofer, I., W. Schneeberger, and B. Freyer (2005). Converting or not converting to organic farming in Austria: Farmer types and their rationale. *Agriculture and Human Values 22*(1), 39–52.

Daxini, A., C. O'Donoghue, M. Ryan, C. Buckley, A. P. Barnes, and K. Daly (2018). Which factors influence farmers' intentions to adopt nutrient management planning? *Journal of Environmental Management 224*, 350–360.

Dessart, F. J., J. Barreiro-Hurlé, and R. van Bavel (2019). Behavioural factors affecting the adoption of sustainable farming practices: A policy-oriented review. *European Review of Agricultural Economics 46*(3), 417–471.

Diederich, J. and T. Goeschl (2014). Willingness to pay for voluntary climate action and its determinants: Field-experimental evidence. *Environmental and Resource Economics 57*(3), 405–429.

Dimitri, C. and H. Baron (2019). Private sector support of the farmer transition to certified organic production systems. *Organic Agriculture 10*, 261–276.

Dunlap, R. E., K. D. Van Liere, A. G. Mertig, and R. E. Jones (2000). New trends in measuring environmental attitudes: Measuring endorsement of the new ecological paradigm: A revised NEP scale. *Journal of Social Issues 56*(3), 425–442.

Espinosa-Goded, M., J. Barreiro-Hurlé, and E. Ruto (2010). What do farmers want from agri-environmental scheme design? A choice experiment approach. *Journal of Agricultural economics 61*(2), 259–273.

Genius, M., C. J. Pantzios, V. Tzouvelekas, et al. (2006). Information acquisition and adoption of organic farming practices. *Journal of Agricultural and Resource Economics 31*(1), 1–21.

Greiner, R. (2016). Factors influencing farmers' participation in contractual biodiversity conservation: A choice experiment with northern Australian pastoralists. *Australian Journal of Agricultural and Resource Economics 60*(1), 1–21.

Hall, K. and E. Rhoades (2010). Influence of subjective norms and communication preferences on grain farmers' attitudes toward organic and non-organic farming. *Journal of Applied Communications 94*(3), 51–65.

Hanemann, W. M. (1984). Welfare evaluations in contingent valuation experiments with discrete responses. *American Journal of Agricultural Economics 66*(3), 332–341.

Hanley, N., S. Mourato, and R. E. Wright (2001). Choice modelling approaches: A superior alternative for environmental valuation? *Journal of Economic Surveys 15*(3), 435–462.

Hensher, D. A. (1982). Functional measurement, individual preference and discrete-choice modelling: Theory and application. *Journal of Economic Psychology 2*(4), 323–335.

Hoi, P. V., A. P. Mol, P. Oosterveer, P. J. van den Brink, and P. T. Huong (2016). Pesticide use in Vietnamese vegetable production: A 10-year study. *International Journal of Agricultural Sustainability 14*(3), 325–338.

Hole, A. R. (2007). A comparison of approaches to estimating confidence intervals for willingness to pay measures. *Health Economics 16*(8), 827–840.

Hole, A. R. (2008). Modelling heterogeneity in patients' preferences for the attributes of a general practitioner appointment. *Journal of Health Economics 27*(4), 1078–1094.

Hynes, S., N. Hanley, et al. (2005). *Analysing Preference Heterogeneity using Random Parameter Logit and Latent Class Modelling Techniques*. Department of Economics, National University of Ireland, Galway.

Jackson, M. O. (2010). *Social and Economic Networks*. Princeton University Press.

Jaeck, M. and R. Lifran (2014). Farmers' Preferences for Production Practices: A Choice Experiment Study in the Rhone River Delta. *Journal of Agricultural Economics 65*(1), 112–130.

Kwanmuang, K., A. Wangyeesen, and H. Shuto (2018). What Leads Farmers to Abandon Coffee Production?: An Experimental Study on Crop Choice in Chumphon Province, Thailand. *Japanese Journal of Agricultural Economics 20*(0), 18–37.

Läpple, D. and H. Kelley (2013). Understanding the uptake of organic farming: Accounting for heterogeneities among Irish farmers. *Ecological Economics 88*, 11–19.

Läpple, D. and H. Kelley (2015). Spatial dependence in the adoption of organic drystock farming in Ireland. *European Review of Agricultural Economics 42*(2), 315–337.

Läpple, D. and T. Van Rensburg (2011). Adoption of organic farming: Are there differences between early and late adoption? *Ecological Economics 70*(7), 1406–1414.

Lazaric, N., F. Le Guel, J. Belin, V. Oltra, S. Lavaud, and A. Douai (2019). Determinants of sustainable consumption in France: The importance of social influence and environmental values. *Journal of Evolutionary Economics*, 1–30.

Lynne, G. D., J. S. Shonkwiler, and L. R. Rola (1988). Attitudes and farmer conservation behavior. *American Journal of Agricultural Economics 70*(1), 12–19.

McFadden, D. (1973). Conditional logit analysis of qualitative choice behavior. *Frontiers in Econometrics 10*, 105–142.

Meijer, E. and J. Rouwendal (2006). Measuring welfare effects in models with random coefficients. *Journal of Applied Econometrics 21*(2), 227–244.

Mergenthaler, M., K. Weinberger, and M. Qaim (2009). Consumer valuation of food quality and food safety attributes in Vietnam. *Review of Agricultural Economics 31*(2), 266–283.

Minot, N. (2006). *Income Diversification and Poverty in the Northern Uplands of Vietnam*, Volume 145. International Food Policy Research Institute.

Mishra, A. K., A. Kumar, P. K. Joshi, A. D'Souza, and G. Tripathi (2018). How can organic rice be a boon to smallholders? Evidence from contract farming in India. *Food Policy 75*, 147–157.

My, N. H., P. Rutsaert, E. J. Van Loo, W. Verbeke, M. H. Nguyen, P. Rutsaert, E. J. Van Loo, and W. Verbeke (2017). Consumers' familiarity with and attitudes towards food quality certifications for rice and vegetables in Vietnam. *Food Control 82*, 74–82.

Nyblom, J., S. Borgatti, J. Roslakka, and M. A. Salo (2003). Statistical analysis of network data - an application to diffusion of innovation. *Social Networks 25*(2), 175–195.

Olli, E., G. Grendstad, and D. Wollebaek (2001). Correlates of environmental behaviors: Bringing back social context. *Environment and Behavior 33*(2), 181–208.

Padel, S. (2001). Conversion to organic farming: A typical example of the diffusion of an innovation? (Special issue: Politics, ideology and practice of organic farming). *Sociologia Ruralis 41*(1), 40–61.

Pham, V. H., A. P. Mol, and P. J. Oosterveer (2009). Market governance for safe food in developing countries: The case of low-pesticide vegetables in Vietnam. *Journal of Environmental Management 91*(2), 380–388.

Pielstick, C. D. (2000). Formal vs. informal leading: A comparative analysis. *Journal of Leadership Studies 7*(3), 99–114.

Pilarova, T., M. Bavorova, and A. Kandakov (2018). Do farmer, household and farm characteristics influence the adoption of sustainable practices? The evidence from the Republic of Moldova. *International Journal of Agricultural Sustainability 16*(4-5), 367–384.

Rapsomanikis, G. (2015). An analysis based on household surveys. In *The Economic Lives of Smallholder Farmers*. Food and Agriculture Organization of the United Nations, Rome, Italy.

Richter, C. H., B. Custer, J. A. Steele, B. A. Wilcox, and J. Xu (2015). Intensified food production and correlated risks to human health in the Greater Mekong Subregion: A systematic review. *Environmental Health: A Global Access Science Source 14*(1), 1–13.

Schneeberger, W., I. Darnhofer, and M. Eder (2002). Barriers to the adoption of organic farming by cash-crop producers in Austria. *American Journal of Alternative Agriculture 17*(1), 24–31.

Schulz, N., G. Breustedt, and U. Latacz-Lohmann (2014). Assessing farmers' willingness to accept "greening": Insights from a discrete choice experiment in Germany. *Journal of Agricultural Economics 65*(1), 26–48.

Sleeth-Keppler, D., R. Perkowitz, and M. Speiser (2017). It's a matter of trust: American judgments of the credibility of informal communicators on solutions to climate change. *Environmental Communication 11*(1), 17–40.

Sligo, F. and C. Massey (2007). Risk, trust and knowledge networks in farmers' learning. *Journal of Rural Studies 23*(2), 170–182.

Spence, M., V. Stancu, C. Elliott, M. Dean, et al. (2018). Exploring consumer purchase intentions towards traceable minced beef and beef steak using the theory of planned behavior. *Food Control 91*, 138–147.

Streletskaya, N. A., S. D. Bell, M. Kecinski, T. Li, S. Banerjee, L. H. Palm-Forster, and D. Pannell (2020). Agricultural adoption and behavioral economics: Bridging the gap. *Applied Economic Perspectives and Policy 42*(1), 54–66.

Thai, N. T., H. T. Manh, and K. Pensupar (2017). Consumers' preferences and willingness to pay for VietGAP vegetables in Hanoi, Vietnam. *International Journal of Economic Research 14*(16), 401–419.

Toan, P. V., Z. Sebesvari, M. Bläsing, I. Rosendahl, and F. G. Renaud (2013). Pesticide management and their residues in sediments and surface and drinking water in the Mekong Delta, Vietnam. *Science of the Total Environment 452*, 28–39.

Train, K. E. (2009). *Discrete Choice Methods With Simulation*. Cambridge university press.

Truong, T. T., M. H. Yap, and E. M. Ineson (2012). Potential Vietnamese consumers' perceptions of organic foods. *British Food Journal 114*(4), 529–543.

Unay Gailhard, İ., M. Bavorová, and F. Pirscher (2015). Adoption of agri-environmental measures by organic farmers: The role of interpersonal communication. *The Journal of Agricultural Education and Extension 21*(2), 127–148.

Van den Broeck, G., P. Vlaeminck, K. Raymaekers, K. Vande Velde, L. Vranken, and M. Maertens (2017). Rice farmers' preferences for fairtrade contracting in Benin: Evidence from a discrete choice experiment. *Journal of Cleaner Production 165*, 846–854.

Van Hoi, P., A. Mol, and P. Oosterveer (2013). State governance of pesticide use and trade in Vietnam. *NJAS - Wageningen Journal of Life Sciences 67*, 19–26.

Villanueva, A. J., J. A. Gómez-Limón, M. Arriaza, and M. Rodríguez-Entrena (2015). The design of agri-environmental schemes: Farmers' preferences in Southern Spain. *Land Use Policy 46*, 142–154.

Weiss, J. and H. Khan (2006). *Poverty Strategies in Asia: A Growth Plus Approach*. Edward Elgar Publishing.

Willer, H. and J. Lernoud (2019). *The World of Organic Agriculture. Statistics and Emerging Trends 2019*. Research Institute of Organic Agriculture FiBL and IFOAM Organics International.

Wollni, M. and C. Andersson (2014). Spatial patterns of organic agriculture adoption: Evidence from Honduras. *Ecological Economics 97*, 120–128.

World Bank (2016). Vietnam food safety risks management: Challenges and opportunities. Technical report, World Bank, Hanoi.

Wu, L., L. Xu, and J. Gao (2011). The acceptability of certified traceable food among Chinese consumers. *British Food Journal 113*(4), 519–534.

Zeng, Y., Y. Tian, K. He, and J. Zhang (2019). Environmental conscience, external incentives and social norms in rice farmers' adoption of pro-environmental agricultural practices in rural Hubei province, China. *Environmental Technology 3330*, 1–40.

Zhengfei, G., A. O. Lansink, A. Wossink, and R. Huirne (2005). Damage control inputs: A comparison of conventional and organic farming systems. *European Review of Agricultural Economics 32*(2), 167–189.

Chapter 6

Conclusion

This dissertation contributes to the existing literature by providing insight into the role of network in promoting the pro-environmental behavior in theoretical and experimental ways. The contribution of the first chapter to the existing literature is to study the effectiveness of several social incentives that help to promote pro-environmental behavior. More specifically, we contribute to the literature by addressing all of the seven groups of social incentives together in order to answer the following question: Which social incentives are more effective than others in encouraging pro-environmental behavior? Moreover, we also took the impact of the aggregation level into account by organizing the seven social incentive groups into three higher aggregated social groups (i.e., social influences, network and trust) and investigated their relative relevance with respect to the metadata. We find that network and internal social influence (i.e., that motivates people to change their perceptions and attitudes) play important role in incentivizing individuals to behave positively toward the environment. The purpose is to quantify the strength and relevance of social incentives in regard to pro-environmental behavior and to give some recommendations in terms of public policy. However, there is one issue which has not been fully addressed, is the impact of country's cultural differences on pro-environmental behavior. This issue is important enough to be investigated in depth in a future study, in which the general characteristic of a national culture can be captured by using the Hofstede's values (??, hof), for example, and adopting a previously proven approach (Morren and Grinstein, 2016). Since in our meta-analysis, several studies conducted in multiple countries, we cannot apply the Hofstede's values to capture the impacts of country's cultural differences. Our meta-regression, however, partially addressed the country heterogeneity by using geographical regions and study-specific effects.

Chapter 2 contributes to the literature by taking the role of social comparison through different network structure (e.g., empty network, star, circle and complete network) into account in promoting the common pool resource conservation. We consider that agents are connected to exogenous networks, meaning that networks are formed by a central planner. An advantage of the exogenous network is that it helps to capture the causal effect of network structures on individual behaviors as network varies. We also distinguish the social comparison into assimilation (i.e., individuals minimize the difference between them and their reference group) and contrast (i.e., individuals maximize the difference between them and their reference group) in comparison and deeply investigate how the assimilation in comparison could play a role in shaping individual behaviors. In this Chapter, we find that the assimilation in social comparison (i.e., changing behaviors in order to fit in with a group) performs sufficiently well in centralized networks (like a star network) compared to decentralized networks (like a circle or complete network) in incentivizing individual to conserve the common pool resource. However, our study has not yet explored the possibility of the contrast in comparison, which agents have incentives to differentiate with their neighbors. The reason is that since there is the "substractability" property of the commons, no agent is willing to differentiate with others by extracting less the common resource. The contrast in comparison will be, however, interesting to be studied if one can justify that there exists the case "doing worse, but feeling better" (Lockwood et al., 2004; Toma, 2013). In other words, ones would feel good by extracting less resource than others. Moreover, we suggest that instead of using Nash equilibrium, we could study this model using the Lindahl equilibrium because in fact, at the equilibrium, each agent shares the same share of the common good but some agents may value the common good differently than others (Franke and Leininger, 2018; Foley, 1970; Lindahl, 1958). However, one of the limitation of the Lindalh equilibrium pricing is we do not exactly know how much each agent values the certain good. But, it is important that the future research could take this issue into consideration.

Chapter 3 contributes to the literature by taking the social influence in endogenous networks into account in order to investigate the individual behaviors in a common pool resource game. The endogenous network assumption makes the model fit well to the reality, where individuals can make decisions in choosing either the effort to extract the resource and the number of neighbors to form links with depending on themselves and their neighborhood performances. Our result suggests that the system of a CPR game is not always locally stable as the network size varies. In particular, we find that the CPR game will become locally unstable if there are more than six agents competing in harvesting a common resource. However, this chapter has several shortcomings which could be addressed by future research. Firstly, since this is the static Nash equilibrium model, the agents did not take their own previous actions into account and thus this makes the model become less realistic. However, this kind of one-shot Nash equilibrium has been studied a lot in the public good game and thus it is simple but it is still very interesting to apply. In fact, in some situations, agents make decision regardless to their own previous behaviors, for example, agents who make their first decisions whether they should contribute to public good or not. Secondly, instead of using simultaneous move game, a sequential game in which agents would play a network formation game (i.e., agents choose their direct neighbors) and then participate in a CPR game with the network given in the previous step, could be also relevant and interesting to be studied. Finally, a strong or weak social influence in networks in our model depends on the social influence parameter. However, in reality, the social influence depends on how strong is the social norm in the agent's network (Gavrilets and Richerson, 2017). Thus, it is important to note that emergence of social norm is out of scope of this study. It is, however, worth to be deeply investigated in a future because the social influence parameter depends on social norms and thus determines whether it is beneficial or not for an agent to initiate a link with his or her target neighbor.

In chapter 4, this dissertation contributes to the experimental literature on role of networks in promoting adoption of organic farming using a contextualized lab-in-the-field experiment. Particularly, we contribute by studying how the social comparison (i.e., information about the average group investment) and information nudge (i.e., information about the socially optimal investment) in the presence of different types of network structures could impact farmers' investment decisions in organic agriculture. In order to capture the causal effect of networks on farmers' behaviors, we consider the organic investment game with the given network structures (exogenous network) and allow the network to vary. Future studies should also take the endogenous structure of the network into account in order to capture which network pattern could result in a higher level of adoption of organic agriculture. Our results suggest that there is a possibility of a *crowd in* effect as the effect of social comparison combined with information nudge exceeds the effect of social comparison (Brandon et al., 2019). However, in this study, we have not yet taken the effect of only information nudge treatment into account, and thus we cannot conclude whether there is a presence of *crowding in* or *out* in social nudges (e.g., social comparison and information nudge). The mechanism of *crowding in and out* in social nudges deserves our attention since it may have important implications in promoting sustainable agriculture.

Chapter 5 contributes to discrete choice experiment literature by taking the role of network and leadership in farmers' preferences as well as several other factors (training and technical advice, sale contract and traceability) into account in order to study farmers' preferences towards organic farming. The use of choice modeling can contribute towards public policy for sustainable agriculture in the context of Vietnam as well as in many other developing countries. These attributes of organic farming adoption have been quantified and hence can be utilized for justification of promoting organic agriculture in Northern Vietnam. However, our results find that farmers' willingness to pay are very different across different types of agricultural products (e.g., rice, vegetables, fruits, corns, etc.). This is not only because of differences in unit cost of different types of products, but because organic farmings of some types of agricultural products (like rice) are more difficult to be accessed and takes longer to cultivate, and more importantly organic rice, for instance, has limited demand and inadequate marketing (i.e., more difficult to market organic rice), compared to organic vegetables or other type of products. Therefore, further research is still needed to establish the actual costs and benefits of organic farming adoption by taking the different types of agricultural products into account in this research area. The complementary cost-benefit analysis can additionally provide policymakers with other benefits that may be caused by long-term reduction of pesticide uses and the uses of other harmful plant protection products. The long-run discount rate should also be considered because the organic farming investment has welfare effects for future generations.

In conclusion, this dissertation contributes to the literature by deeply investigating the role of networks, the role of social incentives (such as, social comparison and information nudge) in networks and its impacts on pro-environmental behaviors (such as, resource extraction and adoption of organic farming). In a more and more connected world, understanding the network structure is essential in order to effectively provide the social incentives to promote the pro-environmental behaviors. For instance, we find that it is effective to encourage social comparison in a network with fewer connections and to provide information nudge to a network with more connections in order to promote the adoption of organic farming. Moreover, since in a real world, the network structure cannot be easily and fully observed, we contribute by also taking the endogenous network (i.e., network is not given and individuals can decide who they would like to form a link with) into account and investigate how social influence in networks could affect individuals' behaviors in a common pool resource game. For instance, we find that when the network endogenous, either a sufficiently low cost of linking and small network size are essential to ensure a stable equilibrium resource extraction. Additionally, instead of using simultaneous move game, a next step is to enlarge this theoretical model by firstly taking the network formation into account (i.e., a sequential game in which agents play a network formation game and then a CPR game with a given network structure in the previous step), and then also applying in studying individuals' behaviors in, for example, a public good or a organic farming investment game (in Chapter 4).

Policy implications

Firstly, our results suggest that the social incentives and networks play important roles in encouraging the pro-environmental behaviors. In other words, public policies, which aim to promote the emergence of pro-environmental behavior, should not be based only on subsidies, but also more essentially on information (e.g., social comparison and information nudges) given, not only to individuals, but also to groups of individuals (e.g., information about the neighborhood actions/behaviors). This is because be a network of neighbors or/and friends is a valuable source of knowledge, information and motivations that helps to incentivize and sustain individual's pro-environmental behaviors (Van Campenhout et al., 2017). Thus, it is important that policymakers and individuals themselves should always try to establish a channel to promote individual-to-individual links as well as to promote individual social identity which can help to strengthen the social comparison and social influence in the network. Moreover, understanding the role of networks (e.g., social/network structures, how individuals interact with each other, etc.) could help policymaker to prioritize between programs targeting on individuals or neighborhood networks to effectively promote the pro-environmental behavior change.

Secondly, in addition to the network connection (i.e., numbers of connections that each individual has), network structure (i.e., decentralized or centralized network) is also important and deserves deep investigation. Our results indicate that promote social incentives (e.g., social comparison and nudges) in different types of network structures result very different impacts of individual behavior change. Our theoretical model also suggests that we can more effectively promote the common resource conservation by encouraging the assimilation social comparison in centralized networks (like a star network) compared to decentralized networks (like a circle or complete network). This means that in a social world where there is at least a central agent who can plays a role in motivating others (e.g., a leader, a seeding, an influencer or an influential person), motivating the role of the central agents could help to significantly promote the common resource conservation. Therefore, in addition to individual-to-individual relationships, policymakers should also take the role of "environmental leader" who takes the first step in creating consciousness, awareness and action on protecting the environment into account in order to promote the pro-environmental behavior (Akiyama et al., 2013). Because an environmental leader could play a role as an example and model to others, he or she could therefore help to effectively drive individuals toward a more sustainable environment.

Thirdly, our results suggest that in a network where everyone can fully observe others' behaviors (e.g., complete network), providing individuals the social comparison (information about their average group/network behavior) has no significant impact on their pro-environmental behaviors. This result is straightforward because when individuals can fully observe others actions/behaviors, social comparison will not play any role as providing individuals additional information about others' behavior. In other words, the comparison effects among individuals in the network dominate the comparison effect of the social comparison (information about their average group/network behavior). However, in reality, it is always very difficult for policymakers to fully observe the actual network structure, and individuals themselves cannot also fully observe the behaviors, actions or decisions of their neighbors/friends. In this situation, providing social comparison to individuals (e.g., feedback on their behaviors and the average behaviors of their neighbors or social comparative feedback), could help to stimulate self-evaluation as well as competition (Allcott and Rogers, 2014; Dupré and Meineri, 2016). Therefore, it helps to shape individuals' behaviors and thus incentivize them to behave positively towards environmental sustainability (Festinger, 1954).

Finally, our analysis reveals that the “social comparison combined with information nudge" has a positive impact on farmers' decisions in encouraging them to invest in organic farming in all types of networks. This indicates that information nudge (i.e., information about the socially optimal behaviors) can help to alter individuals' behaviors in a predictable way (i.e., to behave towards a socially optimal behavior) (Thaler and Sunstein, 2008). For instance, timely reminders about not only the importance of organic agriculture but also the socially optimal organic investment (i.e., information nudge) can help to increase farmers' awareness about organic agriculture and to help them to maintain commitments and schedules (Fabregas et al., 2019). As a result, it helps to nudge them towards bridging the gap between their intentions and their actions. However, we also observe in our study that the effect of “information nudge" can be different depending on different network structures because our theoretical model suggests that the socially optimal is different across different networks. Therefore, nudges related to information are context-specific and thus they should be carefully tested since same nudges might not have the same effect across different subgroups in society (Bénabou and Tirole, 2006).

Bibliography

hofstede's culture dimensions: An independent validation using rokeach's value survey.

Akiyama, T., K. J. An, H. Furumai, and H. Katayama (2013). The concept of environmental leader. In *Environmental Leadership Capacity Building in Higher Education*, pp. 19–40. Springer, Tokyo.

Allcott, H. and T. Rogers (2014). The short-run and long-run effects of behavioral interventions: Experimental evidence from energy conservation. *American Economic Review 104*(10), 3003–37.

Bénabou, R. and J. Tirole (2006). Incentives and prosocial behavior. *American Economic Review 96*(5), 1652–1678.

Brandon, A., J. A. List, R. D. Metcalfe, M. K. Price, and F. Rundhammer (2019). Testing for crowd out in social nudges: Evidence from a natural field experiment in the market for electricity. *Proceedings of the National Academy of Sciences 116*(12), 5293–5298.

Dupré, M. and S. Meineri (2016). Increasing recycling through displaying feedback and social comparative feedback. *Journal of Environmental Psychology 48*, 101–107.

Fabregas, R., M. Kremer, and F. Schilbach (2019). Realizing the potential of digital development: The case of agricultural advice. *Science 366*(6471), 1–9.

Festinger, L. (1954). A theory of social comparison processes. *Human Relations 7*(2), 117–140.

Foley, D. (1970). Lindahl's solution and the core of an economy with public goods. *Econometrica 38*(1), 66–72.

Franke, J. and W. Leininger (2018). Lotteries and Lindahl prices in public good provision. *Journal of Public Economic Theory 20*(6), 840–848.

Gavrilets, S. and P. J. Richerson (2017). Collective action and the evolution of social norm internalization. *Proceedings of the National Academy of Sciences 114*(23), 6068–6073.

Lindahl, E. (1958). Just taxation-a positive solution. In *Classics in the Theory of Public Finance*, pp. 168–176. Springer.

Lockwood, P., D. Dolderman, P. Sadler, and E. Gerchak (2004). Feeling better about doing worse: Social comparisons within romantic relationships. *Journal of Personality and Social Psychology 87*(1), 80.

Morren, M. and A. Grinstein (2016). Explaining environmental behavior across borders: A meta-analysis. *Journal of Environmental Psychology 47*, 91–106.

Thaler, R. and C. Sunstein (2008). *Nudge: Improving Decisions about Health, Wealth, and Happiness*. Yale University Press.

Toma, C. L. (2013). Feeling better but doing worse: Effects of Facebook self-presentation on implicit self-esteem and cognitive task performance. *Media Psychology 16*(2), 199–220.

Van Campenhout, B., W. Walukano, F. Nattembo, L. Nazziwa-Nviiri, and J. Blom (2017). The role of Information in agricultural technology adoption: Experimental evidence from rice farmers in Uganda. *IFPRI Discussion Paper Series 01684/2017*, 1–47.