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LES CHERCHEURS ACADÉMIQUES À LA CROISÉE DE LA SCIENCE INDUSTRIELLE:

LE CAS D'UNE UNIVERSITÉ JAPONAISE.

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FRENCH SUMMARY

Motivation et définition

Cette thèse est composée de diverses contributions qui se concentrent sur les effets qu'ont les influences commerciales sur la science académique. Nous définissons la *science académique* comme une activité ayant principalement lieu dans les universités et financées par des organismes de recherche. Ses principaux outputs sont les articles scientifiques publiés dans des revues de lecture ou des conférences. Nous opposons cette pratique à la *science industrielle* qui se fait principalement au travers de la recherche industrielle. Le terme influence commerciale est caractérisé par deux éléments. Premièrement, il englobe toutes les activités de transfert de technologie que les universitaires peuvent faire. Deuxièmement, il prend en compte l'influence que les partenaires industriels peuvent exercer sur les universitaires dans leurs activités de collaborations de recherche avec les universités. Le coeur de cette thèse est de caractériser, d'évaluer, et comprendre comment les chercheurs académiques sont influencés dans leurs pratiques par leurs contacts avec le monde industrielle et les valeurs et normes qu'ils véhiculent.

Notre unité d'analyse est l'individu, le chercheur académique, nous avons décidé de choisir cette focale car nous voulons nous concentrer principalement sur les déterminants individuels de production de connaissance. De plus, nous concentrerons notre analyse sur les chercheurs exerçant dans les universités et non les organismes publics de recherche. Dans le secteur public, il y a clairement deux types d'institutions (David, 1993): la première consiste dans un engagement direct des pouvoirs publics dans la production et la distribution de la connaissance, la deuxième consiste à subventionner des producteurs indépendants pour entreprendre la recherche. Alors que la première disposition caractérise les laboratoires dits de recherche public, la seconde caractérise les universités. Les motivations des scientifiques et des mécanismes d'allocation des ressources sont fondamentalement différentes dans ces deux institutions. Dans le système universitaire, les individus sont libres de poursuivre des objectifs de recherche qu'ils ont librement fixé. Ainsi, l'une de leurs principales motivations est de résoudre des problèmes scientifiques (Stephan, 1996). En revanche, dans les laboratoires de recherche public, la recherche est organisée par l'Etat par rapport à des objectifs ciblés, comme le développement de l'énergie nucléaire ou la recherche contre le cancer. Dans cette thèse, en parlant de la science académique, nous faisons principalement référence aux travaux scientifiques menés au sein des universités. La raison principale de ce choix est que notre considération majeur est de comprendre comment la "liberté supposé" des universitaires de choisir leurs thèmes de recherche est conditionnée par des considérations commerciales.

En outre, une autre raison impérieuse de mettre l'accent de cette thèse sur les universités est que les systèmes universitaires des pays industrialisés traversent une période de profondes modifications. Depuis le début des années 1980, les politiques et les priorités des universités ont été de plus en plus influencées par la volonté publique de rendre la recherche universitaire attentive aux besoins nationaux et les tendances vers la commercialisation des inventions universitaires. Ces tendances ont conduit certains chercheurs à parler de « capitalisme académique » (Slaughter et Leslie, 1997), ou la montée d'un paradigme entrepreneurial dans les universités qui jouent dorénavant un rôle accru dans l'innovation technologique (Etzkowitz, et al., 2000).

Une des indications les plus pertinentes des changements en cours peut être trouvés dans les interactions accrue entre l'université et l'industrie. Beaucoup d'universités sont de plus en plus impliquées dans les projets de R-D coopérative avec l'industrie. De plus, de nombreuses évidences montrent que les entreprises utilisent les connaissances académiques dans une proportion croissante. L'intensification des interactions peut être attribuée, entre autres, aux événements suivants: une applicabilité industrielle rapide et de fortes interactions entre les industries et les universités dans le développement de la biologie moléculaire, les sciences des matériaux et l'informatique (par exemple, Chandler, et al, 2001;. Gambardella, 1995; Kenney, 1986). Un second élément est le contenu de plus en plus scientifique et technologique de la production industrielle. De nombreuses études empiriques ont montré comment la recherche scientifique menée dans le secteur universitaire est transférée aux entreprises (Jaffe, 1986; Mansfield, 1995). Dans ce contexte, nous pensons que l'exploration de la façon dont les universitaires adaptent leur agenda à ce nouvel environnement est un sujet important car c'est modifications portent en elles un fort potentiel oncogénique sur l'efficacité du système. Sur la base de ces observations, cette thèse abordera les questions suivantes:

- Comment et avec quels instruments peut-on mesurer l'influence des considérations commerciales sur la science académique?
- Quelles sont les motivations des universitaires de se livrer à activités de transfert de technologie?
- Comment la recherche commune avec des partenaires industriels affectent le travail des membres du corps académique?
- Comment les chercheurs académiques adaptent leurs pratiques de recherche aux demandes potentiellement antagoniste de la recherche universitaire et l'industrielle?

En vue d'aborder ces questions, nous fondons tous les travaux empiriques de cette thèse sur une hypothèse théorique forte. Notre postulat de base est d'avancer qu'il y a deux types idéalisés de chercheurs: les scientifiques industriels et académiques. En traçant une ligne entre ces deux types de scientifiques, nous visons à souligner la distinction entre les deux organisations sociales où ils évoluent. Nous n'avons pas l'intention de distinguer ces deux communautés de chercheurs grâce à leur méthode d'enquête ou de rechercher, ou par la nature des connaissance obtenues, mais à travers les objectifs reconnus comme légitimes dans les deux communautés. En particulier, nous insistons dans notre travail sur les différences de comportement en ce qui concerne la divulgation des connaissances et les caractéristiques du système d'évaluation et de récompense. En utilisant cette approche, nous nous plaçons dans les traces du travail développé par Dasgupta et David (1994, 1987).

Dasgupta et David ont lancé un programme de recherche pour ce qu'ils appellent la « New Economics of Science ». Au centre de ce projet se situe essentiellement deux objectifs: le premier est d'expliquer les logiques constituantes qui soustendent les institutions scientifiques, le second est d'examiner les implications des différents arrangements institutionnels mis en place vis-à-vis de l'efficacité de l' allocation des ressources.

Dans ce qui suit, nous expliquons comment nous allons mettre en œuvre ce cadre théorique pour la recherche menée dans cette thèse. Nous expliquons d'abord, plus précisément, comment nous définissons la science académique, par opposition à la science industrielle, en mettant en exergue quelques tendances sur l' influence de la science industrielle sur les chercheurs universitaires. Nous présentons ensuite comment nous allons mesurer ces éléments, et enfin nous présentons notre unité d'analyse: une université de recherche japonaise.

Système académique vs. Système industriel

Nous plaçons au centre de notre travail une hypothèse centrale: les scientifiques universitaires et industriels opèrent sous différents mécanismes institutionnels et normes. À la suite de Dasgupta et David (1987), nous estimons que la science académique est principalement concernée par la poursuite de la croissance du stock de connaissances, tandis que les scientifiques industriels sont intéressés par les rendements privés ou les rentes économiques qui peuvent être tirées de ce stock. Merton (1973) a expliqué que la science est régie par une série de valeurs et de normes, qui ont émergé progressivement à travers des interactions répétées entre les scientifiques. Selon lui, bien que l'éthique de la science n'ait pas été codifiée, elle est néanmoins un élément liant pour ses membres par un ensemble complexe de normes et de valeurs exprimées par une série d '«usage et de coutumes», qui assurent les règles du jeu scientifique. Merton utilise principalement le mot science pour désigner la science académique, mais il ne fait aucun doute que les comportements des chercheurs industriels sont aussi régis par un ensemble complexe de valeurs, normes et croyances. Dans cette ligne de pensée, Ziman (2000) propose un ensemble d'attributs pour définir comment les scientifiques industrielles fonctionnent. Par exemple, il décrit comment les scientifiques industriels produisent des connaissances principalement appelées à être internalisée par leur entreprise, et donc n'ayant pas de visé à être rendue publique. Dans cette thèse nous sommes intéressés à acquérir une meilleure compréhension de ce qui se passe quand ces deux façons de faire de la science se rencontrent. Comprendre comment la science est conduite à l'intersection de l'université et les domaines industriels peut nous aider à identifier si oui ou non, et si oui comment, les normes évoluent grâce à ces interactions. Nous avons l'intention d'étudier l'effet que les considérations commerciales sur la façon dont les chercheurs universitaires organisent et de diffusent leurs travaux.

Une université Japonaise

La partie empirique de la thèse est centrée sur une université. Nous avons décidé de choisir comme unité d'analyse, l'Université du Tohoku, qui est à la pointe de la commercialisation de la science universitaire au Japon. L'université de Tohoku est une université japonaise de premier plan dans les sciences physiques, de la vie et de l'ingénierie, tout en ayant une activité de transfert de technologie importante (plus d'informations sur l'université se trouvent dans l'annexe A). La sélection de cette université a été basée sur trois critères distincts.

Tout d'abord, nous avons décidé d'ancrer notre analyse au niveau "micro". En concentrant nos travaux empiriques sur des données individuelles, nous avons voulu gagner une meilleure compréhension sur le comportement des membres du corps professoral vis-à-vis des activités de commercialisation. Nous avons préféré ce niveau d'analyse des données au niveau national, car les données agrégées au niveau des universités sont encore rares au Japon. Plus important encore, nous souhaitons mettre l'accent sur les déterminants individuels de la production de la recherche académique. Comme Bonaccorsi et Daraio (2007) l'ont remarquées, presque toutes les variables d'intérêt pour la science et la technologie sont répartis de manière inégale. En utilisant des indicateurs nationaux, des spécificités importantes des phénomènes en jeu peuvent être occultés: à notre avis, un niveau local ou même une seule unité d'analyse est plus enclin à décrire les grandes variations que l'on est susceptible de rencontrer lors de l'étude des comportements d'innovation et de recherche.

Deuxièmement, malgré l'abondante littérature sur la commercialisation des technologies des universités et des relations université-industrie, elle est encore largement dominée par le travail sur les universités étasuniennes, et dans une moindre européennes, est encore moins souvent sur les universités asiatiques. Fort de ce constat, nous avons décidé d'élargir l'image en se concentrant sur une grande université japonaise. De cette façon, nous nous sommes inspiré des travaux d'autres chercheurs en se concentrant sur une université de premier plan où les sciences commerciales et académiques semblent se mêler. Dans le cas des États-Unis, Stanford, UCLA, Columbia, et le MIT ont été utilisées comme point de départ pour analyser les relations université-industrie aux États-Unis; pour l'Europe, l'Université Louis Pasteur en France, l'Université catholique de Louvain en Belgique et de l'Ecole Polytechnique Fédérale de Lausanne en Suisse ont donné naissance à des aperçus intéressants.

Troisièmement, ce choix a été dicté par la disponibilité et la fiabilité des sources. Nous avons eu un accès stable et à long terme à l'information concernant l' Université du Tohoku. Cette relation privilégiée a permis d'avoir accès à des données telles que l'information financière, les détails du contrat de recherche, des renseignements sur le personnel, et des documents de brevet non publiées, entre autres. Toutes ces informations sont très sensibles et il n'aurait pas été possible de les obtenir sans une coopération institutionnelle. Notre coopération à long terme avec le service des ressources humaines, l'office de propriété intellectuelle et l' administration du département d'ingénierie, nous a permis de recueillir un ensemble riche de données, d'avoir accès aux principaux chercheurs de l'université, et d'acquérir des connaissances tacites sur la façon dont l'université fonctionne.

Structure de la thèse

La question centrale de la thèse est l'influence exercée par la valorisation sur le processus de production scientifique dans les institutions académiques. Depuis que la recherche de type universitaire est universellement considérée comme un instrument de progrès économique, cette fonction influence de manière croissante (et complexe) les objectifs, les agendas et les pratiques des chercheurs. Les stratégies des « académiques » en matière de production et de diffusion de la connaissance sont en effet notablement modifiées par ce contexte, et de ce point de vue le cas japonais est très intéressant à observer : à la fois dans ses singularités et dans le message universel qu'on peut en tirer. L'Université de Tohoku, une de celles qui est le plus en avance dans le domaine de la « commercialisation » de la recherche au Japon, constitue ainsi un cas paradigmatique.

La construction de la thèse est organisée en cinq parties. Premièrement, nous passons en revue la littérature théorique sur le sujet, ce qui nous permet de définir la notion de «science ouverte» comme mode d'organisation dominant dans le monde universitaire. Nous analysons ensuite l'influence des collaborations industrielles et des impératifs de commercialisation sur ce mode d'organisation de production de connaissances. Deuxièmement, cette formulation théorique est vérifiée empiriquement par une recherche de terrain basée sur des données quantitatives issues de l'Université de Tohoku. Troisièmement, nous utilisons les résultats d'une enquête visant à évaluer la perception des chercheurs de l'université de Tohoku sur le brevetage universitaire. Quatrièmement, l'effet de la collaboration industrielle sur la production académique est étudié en se focalisant sur une étude de cas basée sur un groupe de chercheurs très productifs. Enfin, nous concluons en discutant du concept de co-évolution des pratiques de recherche entre les universités et l'industrie. La suite de ce résumé discutera de chacune des cinq contributions séparément.

Pour commencer, nous abordons trois questions fondamentales en nous basant sur la littérature. Tout d'abord, nous soulignons les propriétés qui font que les connaissances scientifiques sont proches de ce que l'on appelle en économie un « bien public », et nous montrons par la suite que dû à ces propriétés les processus de marché concurrentiel ne sont pas efficaces dans l'allocation des ressources pour une production et distribution optimale des connaissances scientifiques. En relation avec ce problème, nous montrons comment et pourquoi un mode d' organisation a émergé pour permettre une diffusion large et rapide des savoirs académiques. Ce mode d'organisation est appelé «science ouverte», il est constitué d'un système de récompenses non-marchandes qui favorise la production, la validation, et la diffusion des productions scientifiques. Deuxièmement, nous montrons comment la demande de plus en plus forte envers les universités d'effectuer les activités de commercialisation de leurs découvertes affecte l'organisation traditionnelle de la recherche académique. Dans ce processus, nous portons une attention particulière à mettre en évidence l'influence, positive et négative, sur un tel arrangement de la participation de l'industrie dans la recherche universitaire. Nous concluons cette partie par un recensement de la littérature empirique sur les relations université-industrie.

Le deuxième chapitre de la thèse analyse l'influence des brevets universitaires, un proxy pour évaluer leurs activités de commercialisation, sur l'activité de publication, l'output traditionnel des chercheurs universitaires. Pour ce faire, nous avons conçu deux exercices économétriques se focalisant sur l'Université de Tohoku pour tester les relations entre brevets et publications. Dans cette étape, nous avons porté une attention particulière à la méthodologie employée pour prendre en compte la nature de nos données ; en effet nos données principales, les brevets et les publications, sont des nombres entiers, et de par ce fait demandent des méthodologies particulières de traitement. Nos résultats empiriques suggèrent que ces deux activités sont plutôt complémentaires. Ils révèlent aussi l'existence d'un effet de cohorte : la jeune génération, en réponse aux changements des politiques universitaires mis en place au Japon, semble plus enthousiaste à s'engager dans l'activité de brevetage que leurs ainées. Enfin, nos résultats indiquent une influence significative du mode de financement de la recherche sur les niveaux de brevets et publications.

Le troisième chapitre utilise les résultats d'une enquête envoyée aux titulaires de brevets de l'université de Tohoku. Plus précisément, nous avons concentré notre analyse des données issues de l'enquête dans trois directions: premièrement quelle est la motivation d'un chercheur académique à breveter ses résultats ; deuxièmement quelles sont les conséquences d'une telle entreprise ; et troisièmement quelle est l'influence d'une telle démarche sur la formulation de l'agenda de recherche. Pour aborder cette dernière question, nous avons recouru à une analyse quantitative des données. Généralement, nous avons constaté que la participation à une activité de brevetage ne semble pas être préjudiciable aux activités liées aux missions traditionnelles d'un universitaire. Cependant, nous voyons émerger des différences sensibles selon le domaine technologique où un chercheur exerce son activité. Les effets sont plus négatifs sur les normes de la « science ouverte » dans les domaines des sciences de la vie. Les différences de perception de l'activité de brevetage sont aussi marqués selon de type de recherche effectué. Les scientifiques qui ont déclaré faire essentiellement de la recherche fondamentale sont plus susceptibles d'avoir une vision négative à l'égard des effets potentiellement nocifs des brevets sur la liberté académique.

Le quatrième chapitre examine plus en détail l'influence que les collaborations industrielles exercent sur groupe de chercheurs très prolifiques, en termes de publications et brevets, dans le domaine de la science et l'ingénierie des matériaux. Cette discipline a été choisie comme domaine d'investigation car il est à la fois un des domaines d'excellence de l'institution que nous analysons, et qu'il est très fertile en terme de possibilités de commercialisation et de contactes fréquents entre science et industrie. Pour aborder notre question de recherche, nous avons conduit des interviews avec dix chercheurs. Nous les avons sélectionné en opérationnalisant la notion du « Quadrant de Pasteur » mis en avant par Stokes (1997). Les résultats de nos entretiens montrent que des modes distinctifs de collaborations, science-industrie, apparaissent sous la lumière de notre classification, et ils soulignent, aussi, la nécessité d'avoir une approche différenciée dans l'analyse des effets des relations université-industrie.

Dans le dernier chapitre, nous mettons en avant le concept de co-évolution des pratiques de recherche, ou comme il a été mentionné par Foray et Lissoni (2010), l'idée que la recherche universitaire et les activités de transfert de technologie peuvent être considérées comme une «joint product economy». En effet, les résultats de notre travail de thèse ne sont pas arrivés à dévoiler de résultats tranchés sur les effets des collaborations industrielles sur l'éthique universitaire, la réalité est plus complexe. Nous croyons plutôt que l'éthos académique, sous certaines conditions, à tendance à se fondre avec les pratiques des scientifiques travaillant pour l'industrie. Nous concluons plutôt que l'éthos académique, sous certaines conditions, a tendance à se confondre avec les pratiques des scientifiques travaillant pour l’industrie. Nous utilisons la notion de « patent-publication pairs» dévelop-pée par Murray (2002) pour illustrer notre pensée.

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ACKNOWLEDGMENTS

> *Un voyage se passe de motifs. Il ne tarde pas à prouver qu'il se suffit à lui même. On croit qu'on va faire un voyage, mais bientôt c'est le voyage qui vous fait, ou vous défait.*
>
> — Bouvier, *L'usage du monde*, 1963.

This thesis is written using the pronoun "we" and not with the first person. The reason is that this work is the result of a collective process, a long journey that crossed the path of many individuals. In the few lines that follow, I would like to express my gratitude to those who made this thesis much more than it otherwise might have been.

First, nothing would have been possible without the long-lasting support of Pr. Llerena and Pr. Harayama. I had the good fortune to work under their direction, proved to be a phenomenal experience. Throughout the years, they provided me with many research opportunities and supported my endeavors. In my view, they succeeded in finding a balance between monitoring my work and providing me with total academic freedom. I am very thankful to Dominique Foray, Jean-Alain Héraud, Christofer Newfield, Reinhilde Veugelers and John Walsh who have accepted to be part of the jury of this thesis.

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But it is sometimes when we think that everything is lost that the intimation arrives which may save us; one has knocked at all the doors which lead nowhere, and then one stumbles without knowing it on the only door through which one can enter – which one might have sought in vain for hundred years – and it opens of its own accord.

— Marcel Proust, *Le Temps retrouvé*, 1927.

INTRODUCTION

> *[I]n the great chess-board of human society, every single piece has a principle of motion of its own, altogether different from that which the legislature might chuse to impress upon it. If those two principles coincide and act in the same direction, the game of human society will go on easily and harmoniously, and is very likely to be happy and successful. If they are opposite or different, the game will go on miserably, and the society must be at all times in the highest degree of disorder.*
>
> — Adam Smith, *The Theory of Moral Sentiments* (1759)

Overview and motivation

This thesis consists of various contributions, which center on the effects of commercial influences on academic science. We define *academic science* as research mainly conducted in universities and publicly funded research organizations. Its main outcomes are scientific papers. We oppose it to *industrial science*, which is mainly conducted in industrial and governmental research and development (R&D) laboratories. *Commercial influence* is defined by two elements. First, it encompasses all the technology transfer activities that academics may do. Second, it takes into account the influence that industrial partners exercise on academics while engaging in research collaborations with universities.

In the public sector, there are clearly two different types of institutions (David, 1993): the first consists of the government engaging itself directly in the production and distribution of knowledge; the second consists in subsidizing independent producers for undertaking the research. While the first arrangement characterizes the so-called government research laboratories, the second one characterizes universities. Motivations of scientists and resource allocation mechanisms are fundamentally different in these two institutions. In the university system, individuals are free to pursue research targets of their own choice. As a result, one of their main motivations is to solve scientific puzzles (Stephan, 1996). By contrast, in the government laboratories system, research is organized by the state in relation to targeted objectives. In this thesis, while talking about academic science, we will mainly refer to science conducted within universities. The reason being that we are interested in understanding how the supposed "freedom" of choosing research topics within academia is influenced by commercial considerations.

Additionally, another compelling reason to focus this thesis on universities is that university systems within industrialized countries are going through a period of profound modifications. From the early 1980s onwards, policies and priorities of universities have been increasingly influenced by both the quest for relevance of university research to national needs and trends toward commercializing their own academic inventions. These trends led some scholars to talk about "academic capitalism" (Slaughter and Leslie, 1997), or the rise of an entrepreneurial paradigm in which university plays an enhanced role in technological innovation (Etzkowitz, et al., 2000).

One of the most pertinent indications of the ongoing change can be found in the increased interactions between university and industry. Many universities are more and more involved in co-operative R&D projects with industry. Firms are using academic knowledge to an increasing extent. The intensification of the interactions can be attributed, among others, to the following events. High levels of applicability and strong interactions between industries and universities in the development of molecular biology, materials science and computer science (e.g. Chandler, et al., 2001; Gambardella, 1995; Kenney, 1986). A second event is the growing scientific and technological content of industrial production. Many empirical studies have shown how scientific research conducted in the academic sector of the economy spills over to firms (e.g. Jaffe, 1986; Mansfield, 1995). In that context, we feel that exploring how academics respond to these changes is an urgent subject to address as it has applications on the efficiency of the system. Based on these observations, this thesis will tackle the following questions:

- How and with which instruments can we measure the influence of commercial consideration on academic science?

- What are the academics' motivations to engage in technology transfer activities?

- How does joint research with industrial partners affect the work of faculty members?

- How do faculty members adapt their research practices to the potentially antagonist demands of university and industry research?

In order to approach these questions, we base all empirical works of this thesis on a strong theoretical assumption. Our baseline premise is that we think there are two idealized kinds of researchers: industrial and academic scientists. By drawing a line between these two types of scientists, we aim to stress the distinction between the social organizations they are evolving in. We do not intend to distinguish these two communities of researchers through their method of inquiry, or through the nature of the knowledge obtained, but through the goals accepted as legitimate within the two communities. Particularly, we will stress in our work the differences of behavior regarding the disclosure of knowledge and the features of the reward system. Using this approach, we place ourselves in the footsteps of the work developed by Dasgupta and David (1994; 1987). Dasgupta and David have launched a program of research for what they call the "New Economics of Science". At the center of this project lies two goals: the first is to explain the logics underlying the institutions of science; the second is to examine the implications of the different institutional elements for the efficiency of the allocation of resources. In what follows, we explain how we will implement this framework to the research conducted in this thesis. We first explain, more precisely, how we define academic science as opposed to industrial science, providing a few hints on the influence of industrial science on academics. We then highlight how we will measure these elements and finally introduce our main unit of analysis.

Academic organization vs. Industrial organization

We place at the center of our work a central hypothesis: academic and industrial scientists operate under different institutional mechanisms and norms. Following Dasgupta and David (1987), we argue that academic science is mainly concerned by furthering the growth of the stock of knowledge, while industrial scientists are interested in the private returns or economic rents that can be earned from that stock. Merton (1973) explained that science is governed by a series of values and norms, which have emerged progressively through repeated interactions among scientists. According to him, although the ethos of science has not been codified, it is nevertheless binding its members by a complex set of norms and values expressed by a series of "use and wont", which provide the rules of the scientific game. Merton mainly uses the word science to refer to academic science, but there is no doubt that industrial scientists' behaviors are governed by a complex set of values, norms and beliefs as well. In this line of thought, Ziman (2000) proposes a set of attributes to define how industrial scientists operate. For instance, he describes how industrial scientists produce mainly proprietary knowledge, which as such is not necessarily made public. In this thesis we are interested in gaining a better grasp of what happens when these two ways of making science meet. Understanding how science is conducted at the intersection of the university and industrial spheres can help us pinpoint whether or not, and indeed how, norms are evolving through these interactions. As science organization is a complex system responding opportunistically to changing circumstances, we intend to investigate the effect that commercial considerations have on the way academic researchers organize and diffuse their work.

Adaptation, conflicts and evolution

In recent years, the cultures of industrial and academic science have begun to merge. This is a complex, pervasive process, driven by forces that are not yet well understood. Some scholars have called the hybrid research culture that is now emerging "Mode 2" to differentiate it from the more traditional style of "Mode 1"

(Gibbons, et al., 1994). “Mode 2” refers to what Gibbons et al. call a new kind of production of knowledge, which is context-driven, interdisciplinary and brings together multidisciplinary team of researchers. In the same line of thought, Ziman (1998; 2000) describes the rise of "post-academic" science. He uses this terminology to show how this emerging arrangement preserves many academic practices and is still partially located in academia, while many aspects are departing from the traditional Mertonian view. Indeed, Ziman argues that post-academic research is characterized by the completion of various projects, initiated by funding bodies whose members are not usually scientists. The important point here is that it is not up to individual researchers to determine for themselves the projects they embark on, but rather the selection of projects is conditioned to their potential economic and social impact. A logical conclusion of this tendency is that academic researchers are no longer interested in devoting their time entirely to the pursuit of knowledge “for its own sake.” They are encouraged by the university administration to seek industrial funding for commissioned research and to exploit patentable discoveries resulting from their research. This last sentence exposes two key elements that are at the center of our analysis: “commissioned research” and “patents". In order to measure the elements pointing towards a hybrid research culture, we need to find some empirical elements to build upon. Following our baseline strategy, we look for some elements that characterize the research conducted by the members of these two communities. These elements need to comply with two constraints: first, to be available for empirical research and second, to be emblematic of their respective communities. As a result, we decided to center our empirical approach on patent and scientific publications (papers). Most studies focusing on the university-industry relations focus on these two types of data, because they can now be retrieved digitally from electronic databases. Moreover, even if this tendency is not clear-cut, papers are the traditional expected output of university scientists and patents are the favored output of industrial scientists. In this thesis we extensively use these two categories of data to analyze whether university researchers are responding to the new opportunities and constraints offered by a “post-academic” regime. This choice led us to ask ourselves the following questions:

- Is patenting detrimental to the productivity of academic researchers?
- What is the link between academic patenting, publishing, and sources of funding?
- What is the profile of an academic patentee? Old or young; engineer or mathematician?
- Do patenting and publishing target the same audience?

We will address these questions using different empirical techniques. We believe that quantitative and qualitative methods are bound to reinforce each other. To overcome the limitations of purely quantitative research, this thesis combines both quantitative and qualitative work. In this thesis, we will run econometric analyses to explore the link between publishing and patenting. We will then explore in more depth the results of such methods by looking at survey answers and interviews. There are, in our view, two critical advantages in combining quantitative and qualitative data: first, there may be key interactions in the scientific process not captured by patent and paper metrics; second, it allows a triangulation of the results, which can amplify or reduce the scope of the results, eventually broadening their range.

A Japanese university

The empirical part of the thesis is centered on one university. We have decided to choose, as our unit of analysis, Tohoku University, which is at the forefront of the commercialization of academic science in Japan. Tohoku University is a prominent Japanese university with strong academic records in science and engineering, and a vivid technology transfer activity (more about the university can be found in Appendix A). This selection was based on three separate criteria.

First, we decided to anchor our analysis at the micro level. By focusing our empirical work on individual data, we aimed for a better grasp on the faculty members' behavior towards commercialization. We preferred this level of analysis as national level data on universities is still scarce in Japan. More importantly, we wish to focus on individual and laboratory determinants of research production. As Bonaccorsi and Daraio (2007) pointed out, almost all variables of interest in science and technology are distributed unevenly with a very skewed distribution. By using national indicators, we might have missed important specificities of the phenomena at stake: in our view, a local or even an individual unit of analysis is more prone to depict the wide variations that one is likely to encounter when studying faculty members' behavior and output.

Second, notwithstanding the growing literature on university technology commercialization and university-industry relationships, it is still largely dominated by work on universities in the US, and to a smaller extent Europe, with scarce published research on universities in Asia. It is with this in mind that we have decided to broaden the picture by focusing on a leading Japanese university. In that way, we mimicked the pursuit of other scholars by focusing on a prominent university where commercial and academic sciences appear to mingle. In the case of the US, Stanford, UCLA, Columbia, and MIT were used as a starting point to analyze university-industry relationships in the US; for Europe, University Louis Pasteur in France, the Catholic University of Leuven in Belgium and Ecole Polytechnique Fédérale de Lausanne in Switzerland gave birth to interesting insights.

Third, this choice was dictated by availability and reliability. We have stable and long-term access to information at Tohoku University. This special relationship made it possible to have access to data such as financial information, research contract details, personal information, email contacts and unpublished patent documents among others. All this information is very sensitive and would not have been available without institutional cooperation. Our long-term cooperation with the human resources department, the intellectual property office, the center for research strategy and support (CRESS) and the administration of the engineering department, allowed us to gather a rich set of data, to have access to key researchers, and to gain tacit knowledge on the way the university operates.[1]

[1]Most of the empirical research in this thesis was conducted during a 10 months stay at the

By analyzing the relation between commercialization imperatives and academic outputs in a university which is at the forefront of commercialization trends, we wish to highlight important tendencies while simultaneously drawing comparisons between approaches by different universities. Through Tohoku University, we aim to investigate differences and similarities compared to the established models from North American and European universities. A number of interesting questions are raised in reference to the relative acceptance of commercialization as a major mission of the universities, the institutional mechanisms for managing technology transfer and commercialization, and the relative emphasis on industry collaboration versus patenting. Nevertheless, we are aware that the next step will be to broaden the analysis to more universities to get a better view of the Japanese experience. We hope that this present work will create the momentum to enlarge this research to a wider context.

Outline

The central question of this thesis is: how is the ability of faculty members to produce and diffuse scientific and technical knowledge conditioned by their implications in technology transfer activities, collaborations with the industrial scientific community, or some combination of these factors. The five chapters in this dissertation revolve around this question.

In Chapter 1, we begin this thesis by drawing answers from the literature to three main questions. First, we highlight the fact that scientific knowledge is relatively close to a public good: competitive market processes will not do an efficient job allocating resources for the production and distribution of scientific knowledge. We show more specifically how and why the "open science" arrangement has emerged as a non-market reward system that favors the production and dissemination of academic knowledge. Second, we stress the increasing demand on universities to fulfill commercializing activities for their discoveries and attempt to

department of management of science and technology in the graduate school of engineering, which was made possible by the French-Japanese Doctoral School, and a 3 months fellowship awarded by the Japanese Society for the Promotion of Science (JSPS) in 2009. I gratefully acknowledge their support.

show how this may affect the “open science” setting of doing research. We focus, in particular, on the positive and negative influences of industrial involvement in university research. We conclude this chapter with a survey of the empirical literature centered on different issues related to university-industry relations.

Chapter 2 investigates the influence of academic patenting (a proxy for industrial consideration) on publication (the traditional output of university researchers). We perform two econometric tests on Tohoku University faculty to study the relation between patents, publications, and funding. Important methodological steps were devised to take into consideration the nature of the data: patent and publications are positive integers (count variables). The empirical results suggest that these two activities are rather complementary. It also reveals the existence of a cohort effect: the younger generation, in response to policy changes, seems more willing to engage in patenting activity than their older peers. Finally, the results indicate a significant influence of the funding regime on patenting and publishing.

Chapter 3 presents the results of a survey sent to academic patentees. We focus our attention on three main questions: what is the patentees’ motivation in engaging into patenting, what are the consequences of such an undertaking, and how does it influence their research agenda. To answer the last question, we run an econometric analysis. We find that academic patenting does not impede on the traditional missions of our academic patentees. However, we observe slight differences between technological fields and types of researchers: effects tend to be more negative on the norms of open science in the life science fields, and scientists who qualified themselves as conducting mainly basic research are more likely to be negative about the effects of university patenting on academic freedom.

Chapter 4 explores in more depth how industrial collaborations affect a selected group of prolific researchers in the field of materials science. The field of materials science was chosen because it is a field of excellence at Tohoku University, and because of its characteristics that make it prone to industrial collaborations. We use the concept of Pasteur’s Quadrant, first introduced by Stokes (1997), to define three idealized types of researchers. The results from the interviews show that distinctive patterns of collaborations are emerging from this classification. Furthermore, they stress the need to have a differentiated approach on university-industry relations depending on research fields and types of research.

In Chapter 5, parallel to the previous one, we put forward the concept of hybridity of research practices between the two communities. In a position in which academic and commercial dimensions are both present, an academic scientist is likely to be influenced by both norms and practices of the two entities. In that process, new arrangements emerge to cope with often contrasting demands from the two communities. Indeed, there does not seem to be a clear-cut picture on the effects of industrial collaboration on the academic ethos. Instead, we believe that the academic ethos might blend in some ways with industrial practices. We use the concept of patent-publication pairs developed by Murray (2002) to illustrate our thinking.

CHAPTER 1

ACADEMIC SCIENTISTS AND INDUSTRIAL INFLUENCE: A REVIEW

> *It is socially desirable that as much of our basic research effort as possible be undertaken in institutions interested in the quick publication of research results if marginal cost are comparable. In the absence of incentives to private firms to publish research results quickly (such incentive may be legislated) a dollar spent on basic research in a university laboratory is worth more to the society than a dollar spent in the industry laboratory, again, if productivity is comparable.*
>
> — Nelson (1959)

1.1 Introduction

The focus of this chapter is to study the impact of industrial science on academic scientists.[1] Our aim is to portray how university science is organized, and how industrial relations and commercialization opportunities affect the conduct of university scientists. However, in order to assess such an impact, it is worth exploring first the notion of "open science" and the major role it plays in defining how academics organize their work. Such a bypass is necessary as much of the day-to-day practices of academic researchers take root in institutional arrangements one could characterize as "opened". Careful consideration of the "open science" setting shall cast some light on the opening quotation of Richard Nelson: indeed why does the society need "quick publication of research results" and why do univer-

[1] Throughout the thesis we will use interchangeably the terms academics, faculty members, university researchers and academic scientists.

sities have a comparative advantage in accomplishing this task? These two questions are addressed in this chapter. More generally, we lay down the foundations of the thesis by expressing how academics are conducting their research in opposition to a mode of production of knowledge, characterized by industry. By defining common points, differences and potential convergences between academic and industrial science, we create the necessary conditions for a sound empirical work in the following chapters.

Understanding this dynamics is important as the institutional settings where the academics are evolving are changing. Until recently universities have been preoccupied with two missions: research, mainly of fundamental nature, and teaching. These two activities have been beneficial to the society as a whole by providing human capital and basic knowledge to the society. On top of that, recent developments have moved forward a *third mission* for universities: contributing to innovation. Indeed universities play an important role as a source of new knowledge, and on occasion, industrially relevant technologies. Since the 1970s, governments have pushed to increase the rate of transfer of academic research to industry and facilitate their utilization by national firms as part of a broader effort to improve national economic performance in a "knowledge-based" environment. As a result there has been a global rise in the level of involvement of universities in technology commercialization activities, creating a desire to comprehend the influence of university technology transfer and commercialization of its traditional missions.

Clearly, there is a need for a better understanding of the rationale underlying the academic production of knowledge and the influence that this mingling with the industry has on academic research. In order to achieve this task, our inquiry mobilizes, by order of importance, insights from the fields of economics, management, and sociology. In turn, this chapter introduces the concept of open science, the Mertonian norms of science, and then analyzes the cross-fertilization of research practices between industrial and academic researchers. Additionally, in all that follows we put a special emphasis on patents and publications, as they are practical empirical tools to assess how norms and values are challenged at the frontier of academic and industrial domains.

This chapter is divided into three main sections. Section 1.2 defines key terms and notions we will encounter throughout this thesis. It is here that we define and demonstrate our interpretation of knowledge in the light of the economic literature, a central element of our analysis. We then carefully sketch the ethos, norms, and practices of the science and technology sphere, and obliquely of university and industry. We finish by exploring different issues related to university-industry relations.

Section 1.3 sets out an overview of the empirical evidence concerning the impact of commercialization activities on university science. In particular, we build our analysis on works centered on academic patenting, as this tool is often used in the literature as a proxy to materialize commercialization activities of faculty members, as opposed to academic publications which are supposedly more aligned with university missions.

Section 1.4 offers some considerations on the different opportunities that arise according to the type of research a scientists is conducting. We conclude by presenting the driving factors behind scientists engagements in academic patenting (scientist level), and to the different opportunities associated with scientific disciplines (scientific level). More generally, this chapter introduces concepts and lay down a conceptual framework that we will mobilize throughout the thesis.

1.2 The open science arrangement

> Open science is a quite recent social innovation, at least by historical standards. Accompanying the profound epistemological reorientation wrought by the fusion of experimentalism with Renaissance mathematics, the cultural ethos and social organization of Western European scientific activities during the late 16th and 17th centuries underwent a significant transformation, a break from the previously dominant regime of "secrecy in the pursuit of nature's secrets." This change should be seen as a distinctive and vital aspect of the Scientific Revolution, from which there crystallized a new set of conventions, incentive structures, and institutional mechanisms that reinforced scientific researchers' commitments to rapid disclosure and wider dissemination of their discoveries and inventions.
> (David, 1998a)

The first part of this literature review is organized as follows. First, we spend some time defining the basic concepts we will use throughout the thesis (1.2.1) and particularly stress the implications of the public good nature of knowledge and how this element has been treated in the economic literature (1.2.2). We then move to the introduction of the concepts of "open science" and Mertonian norms, as these elements are important to understand the different dynamics at stake in the production of scientific knowledge (1.2.3 & 1.2.4 & 1.2.5). We finish by presenting some salient elements needed to comprehend university-industry collaborations (1.2.6 & 1.2.7).

1.2.1 Memorandum of understanding: science, research activity, and applied *vs.* basic research

The prime goal of this first section is to carve out the different mechanisms at stake in conducting university science, with special attention given to the influence that industrial collaborations have on such endeavors. In order to do so, we define the terms we will use repeatedly, and put limits on how we are going to employ them.

The first such reoccurring word is *science*. As the Oxford English dictionary states it, science is an "intellectual and practical activity encompassing the systematic study of the structure and behavior of the physical and natural world through observation and experiment". In trying to uncover the mysteries of nature, the scientist conducts *research*. "Scientific research may be defined as the human activity directed towards the advancement of knowledge, where knowledge is of two roughly separable sorts: facts or data observed in reproducible experiments and theories or relationships between facts" (Nelson 1959, p. 299). Additionally, we want to stress that science is not a steady state. It should rather be seen as an evolutionary process. Science evolves in nonlinear spikes and downs, new theories are proposed, tried and rise or collapse. As argued by Kuhn (1962), advances in science do not come in a linear way but are rather subject to periodic revolutions, also called "paradigm shifts". According to him, a mature science alternates between phases of normal science, and phases characterized by relative stability of the scientific corpus, a strong accumulation of knowledge, and revolutions.

In the same line of thought, Mulkay et al. (1975) describe a sequential evolution of science. They define three phases in the evolution of research works: emergence, growth, and decline of scientific research. The first is characterized by an exploratory phase, where communication is difficult among the members of the community as a lack of a common language understanding and imprecisely defined problem sets make the inquiry difficult and slow. The second phase sees a rapid growth for fields that are indeed explored and developed, along with an increasing social and intellectual integration made possible by improved channels of communication among the members of the research community. A scientific consensus emerges from a process of negotiation, permitting the institutionalization of the field. This however leads the field to be less productive as the research is routinized, the network grows and opportunities diminish.[2]

In the same vein, Crane (1972) studying the evolution of a given emerging field of research over a 25 years period, reports that most of the main discoveries are found in the first 10 years while the scientific community is still quite small, whereas relatively little is discovered in the remaining period when the topic becomes more comprehensive. As described by Karl Popper (1959), the state of scientific knowledge at anytime is the deposit of observation and conceptual schemes, which have stood the test of time and are still useful in predicting and explain-

[2]For a seminal account on the *Science in Action* to understand how scientific facts and technical machines emerge, we direct the reader to Bruno Latour's book (1987).

ing. The scientific community is questioning new theories and facts, science is a social construction, as theories are challenged and evolving throughout controversies in the scientific community. What we want to stress here is that the scientific endeavor is a collective process where individuals challenge each other's theories. The progress of scientific and technological knowledge is a cumulative process, one that stands on the widespread disclosure of research findings, so they can be tested by the scientific community, to be confirmed or discharged if wrong. This collective dimension of science is reflected by the common use of "we" in scientific manuscripts. According to Harold Varmus, Nobel Prize and former head of the National Institute for Health, USA, it goes like this:

> "We" is the pronoun most commonly used in many fields of science because most-experimental work is performed – and subsequent manuscripts are co-authored – by teams composed of faculty members, post-doctoral fellows, graduate students, and technicians. Sometimes, my use of "we" has referred to such laboratory teams. But, at least often, the "we" referred to that common relationship in science: a sustained partnership between faculty colleagues. (Varmus, 2009)

This collective aspect of knowledge creation is not limited to scientists. Making a excursus to the theory of the firm, we can refer to Nonaka and Takeuchi's theory of organizational knowledge creation. In their view, shared cognition and collective learning constitute the foundation of organizational knowledge creation (Nonaka, 1994; Nonaka and Takeuchi, 1995). At the heart of their theory is the idea that organizational knowledge creation is a process of mobilizing individual tacit knowledge and fostering its interaction with an explicit knowledge base. They argue that knowledge needs a context to be created. They use the Japanese character "ba" which literally means "place," to describe such a context. "Ba" provides a shared social and mental space for the interpretation of information, interaction, and emerging relationships that serve as a foundation for knowledge creation. In our context, such a place will not be the firm, but the university where interactions generate new knowledge.

Now that we have put forward the idea that scientific knowledge is a collective enterprise, we will describe in more specific terms the different characterizations of scientific knowledge. For the student of technological progress, a first useful distinction is the one between generic knowledge and specific application. Intuitively, the latter seems to be of more use for the industry, while the former better frames in the more ethereal world of academia. In a similar vein, Nelson (1959) makes a distinction between *applied research*, which is dedicated to solving a practical problem, and *basic research*, where the goal is knowledge for its own sake. On a more operational term, the Frascatti Manual[3] defines Research & Development (R&D) as encompassing both the production of new knowledge and new practical applications of knowledge. In this vein, R&D is conceived as covering three different kinds of activities: basic research, applied research, and experimental development—these categories are distinguished in terms of their distance from application.

However, these classifications can be difficult to internalize by the researchers themselves. In his Nobel lecture William Shockley, one of the inventors of the semiconductor, stated: "Frequently I have been asked if an experiment I have planned is pure or applied science; to me it is more important to know if the experiment will yield new and probably enduring knowledge in nature."[4] One of the problems driving this misconception may be rhetorical. By drawing a line between applied and basic research essentially based on epistemic criteria, that is, in the difference of nature between scientific findings themselves, confusion is likely to arise. Another mode of classification could be to distinguish between research modes or processes, rather than among research outcomes, according to whether the former are more or less compatible with the objectives of basic researchers in increasing the reliable stock of scientific knowledge. The advantage of this method of classification is that it enables us to center our analysis on the distinctive institutional and organizational modes of the science rather than on an ever-changing definition of basic and applied research. To put it simply, while referring to basic/applied research dichotomy we shall refer mainly to the differences in the social organization of the inquiry process. Companies may a do conduct basic research, universities

[3]The OECD's operating statistical manual for R&D data collection. The first edition of the manual was the result of an OECD meeting of national experts on R&D statistics in Frascati, Italy, in 1963.

[4]As cited in Nelson (1962).

do applied researches, but as we shall soon introduce the members of these two communities operate under different contexts, with different norms and values. [5]

Yet, while having a first naïve approach to the university-industry relationships (UIR), we still redeem the dichotomy between *basic* and *applied* research as an introductive step. Using the so-called "linear model" of innovation, we can pen a stylized vision of the interactions between the two types of actors. A university scientist performs basic or fundamental research, leading to a discovery recognized by a business firm, which may want to collaborate with the university to develop it. The story here is that, often, universities and companies are conducting research with different focuses in mind, the former being more basic and fundamental than the latter. It is however important to stop and notice that this might not always be the case: some companies might focus on rather fundamental problems and some university departments may be highly "application" oriented. Again, the main difference between industry and academia does not reside in the basic vs. applied dichotomy but rather in the norms and values governing their scientific activities. Much university research useful to the industry is also valued by academics. Although some academics draw a line between industrially relevant applied work and more fundamental research, a good deal of high quality academic research is of use for the industry. US-based studies by Mansfield (1995) and Narin et al. (1997a) suggest that a high proportion of industrially significant research is publicly funded, performed in prestigious universities and published in high quality journals. As a consequence, in this thesis we will focus on different degrees of openness of the research setting, the different types of channels to diffuse scientific and technological knowledge, and social norms defining research practices rather than debating over epistemic considerations about separate types of research.

So far in our analysis, the word knowledge has been used freely and lacks a proper definition. In the next section, we address this issue by clarifying how we refer to it, and specifically define some of the important characteristics that make it such a special term for economists.

[5] See Stokes (1997, chap. 1) for a discussion on the different ways to categorize basic and applied types of research.

1.2.2 Characteristics of knowledge production

a. The public good characteristics of knowledge

We can start by the truism that *knowledge* is what we know. More precisely, we might say that knowledge is a subset of information, but it is a subset that has been extracted, filtered, or formatted in a very particular way, that has been internalized by the individuals who use it. Simply speaking, a definition of knowledge that fits our purpose is given by Dasgupta and David (1994):

> By the term "information" (following common usage in economics) we will mean knowledge reduced and converted into messages that can be easily communicated among decision agents; messages have 'information content' when receipt of them causes some change of state in the recipient, or action. Transformation of knowledge into information is, therefore, a necessary condition for the exchange of knowledge as a commodity. "Codification" of knowledge is a step in the process of reduction and conversion which renders the transmission, verification, storage and reproduction of information all the less costly.

This definition of knowledge is relatively broad, nevertheless it stresses the information content and the need of some sort of codification to transmit knowledge. As an example, scientific knowledge is a rather codified piece of knowledge which is transmitted, verified and diffused to the community mainly through conferences and academic publications. We do not intend to dwell on a more precise definition of the term knowledge. We shall rather focus on its characteristics as an economic good to be supplied. Knowledge is not an ordinary commodity, but has several properties that associate it to the general class of *public goods*. On this theme, the writings of Richard Nelson (1959) and Kenneth Arrow (1962) are seminal contributions that describe the public good characteristics of knowledge.[6,7]They showed

[6]Both Nelson and Arrow were affiliated to the RAND corporation at the time of their writing. Their results can be appreciated in a cold-war rhetoric. Indeed, they formulate the view that there is an inherent underinvestment in basic research by private entities, echoing to the belief by the scientific community that the US had failed to beat the Soviet Union in space because it was not investing enough in basic research (Hounshell, 1987).

[7] In his paper, Arrow talks about inventions, however he interprets it broadly as the production of knowledge. According to him, an invention is not characterized by its aim, the discovery of new products, but by its attribute knowledge. He sees, quite simply, knowledge as a sum of the information it contains. Because information is reproducible at low costs and in great quantities without altering its quality, the market for knowledge is doomed to fail.

that due to the joint properties of *non-excludability* and *non-rivalry* characterizing the consumption of scientific knowledge, the inventor cannot fully appropriate the results of his research. Therefore, private investment in research is bounded to be at socially suboptimal level. Moreover, Arrow (1962) assumes that the marginal costs of duplicating scientific knowledge are very low, which will further hamper any market for such a commodity. Furthermore, it is argued that due to the public good nature of knowledge, the producer cannot capture the benefits stemming from the production of new knowledge and therefore market forces remain inadequate in delivering the socially optimal level of scientific research. Let us look briefly at each instance.

Knowledge may be considered a public good due to three particular properties. The first one is non-rival possession, which is made possible by the perfect expandability of ideas. The second is its low marginal cost of reproduction and distribution, which makes it difficult to exclude others from accessing it. Third, there is a substantial fixed cost of original production.

Knowledge has the marvelous property of expendability: it can be passed from one individual to another without losing its value. It can be used simultaneously for the benefit of an infinite number of agents without becoming depleted through intensive use. Thomas Jefferson, writing in 1813, remarked upon this attribute which permits the same knowledge to be used jointly by many individuals at once: "He who receives an idea from me, receives instruction himself without lessening mine; as he who lights his taper at mine receives light without darkening me..."[8] This reflects the non-rival attribute of knowledge. It comes from the fact that although it is expensive to generate the first unit of knowledge, any further use comes at a negligible cost. Thus, while there may be some costs in collecting and learning how to use the new information, such cost do not contradict the idea that further use will not deplete the commodity. The process of learning how to read musical notes is for most a painstaking experience but once mastered, music can be played over and over from a partition. In the words of economic theory, it logically follows that it would be socially undesirable to exclude someone from

[8]The passage of T. Jefferson is quoted from David (2001).

enjoying new knowledge, as the marginal cost of reproduction is low, or even null. However, on the private level, incentives for the producer of knowledge to produce new ideas, artifacts, inventions are left at low ebb due to this lack of *appropriability*.

A related property of knowledge is that it is difficult to retain exclusive possession of it whilst putting it in use. This property is referred to as *indivisibility*: for the value of a given piece of knowledge to be known, it needs to be revealed to the potential buyer. However, if we suppose that this knowledge could be replicated at a low cost once transmitted, the value of it will plunge to zero. In that sense, it is costly to exclude someone to use knowledge once it has been revealed. Hence, he who owns the information should keep it to himself if he wants to use it profitably. Arrow (1962) points out that a seller would need to disclose information on an invention to the potential buyer in order for him to value it. But once it is disclosed the buyer has acquired it at no cost. Even if only little information is disclosed to the buyer it may be enough for him to jeopardize the exclusivity of its possession, the knowledge that something can be done being in itself an important step forward in discovering how it may be done. This property is sometime referred as the "Arrow paradox": if the potential buyer does not know the content of the information, he cannot appreciate its value, but if he knows it, he does not need to buy it any longer.[9]

The dual properties of non-rival use and costly exclusion of others from possession make knowledge difficult to appropriate by its producer. It does not mean that markets cannot supply such a commodity, nor that it needs to be wholly supplied by non-market institutions. Nevertheless market forces will not do an efficient work in allocating resources for the production and distribution of knowledge, thereby reaching a socially optimal level. As stated by Arrow, "for optimal allocation to invention it would be necessary for the government or some other agency not governed by profit-and-loss criteria to finance research and invention"

[9] An vivid illustration of this paradox is the story of Robert Kearns the inventor of the intermittent windshield wiper. He disclosed his idea to Ford motor and other car companies to convince them in licensing the technology. They refused, but proposed few years later nearly the same technology on their vehicles. This story is portrayed in the film *Flash of Genius* (2008).

(ibid., p.623). This statement stresses an important point we shall address in the next sections: to stimulate invention and research, some mechanisms need to be put in place, such as the patent system or the institutional arrangement of "open science".

b. Knowledge externality and spillovers

The argument we developed in the previous section is linked to well-known problems of externalities. Indeed, the lack of full appropriability of scientific knowledge reduces the incentive to engage in research on the side of private for-profit firms. This market failure occurs when a new bit of knowledge has been revealed and some benefits "spill over" to others who will be able to access it without compensation.[10] These spillovers are what economists call *externalities*. Broadly speaking, an externality is defined by two characteristics: first, indirect effects of consumption or production activity influence agents other than the one at the origin of such activity; second, this effect is not transmitted through the price system.[11] Externalities can be defined as negative (the case of environmental pollution) or positive, when one is enjoying the benefits of a good without providing compensation (enjoying music played by a neighbor). The main point here, is that these exchanges are not subject to market mediation. In presence of externalities, the first welfare theorem (the fact that any competitive equilibrium is Pareto efficient) does not hold, the market equilibrium is not a social optimum. In our case of positive knowledge externalities, the private return of producing this knowledge is lower than the social return, leading to a sub-optimal production of the commodity as it would be sociably desirable.

This model applies well to theoretical economic world where knowledge spills easily from the producer to a potential receiver. Several researchers have questioned whether knowledge spillovers occur as easily as portrayed by Nelson and Arrow.[12] The first line of argument is that knowledge is composed of a tacit part

[10]Quite interestingly the etymology of "spill" comes from the old English spillan – kill, destroy, waste, shed (blood) – in that way spillovers can be apprehended as destroying market efficiency.

[11]For a concise treatment of the question one can refer to Laffont (2008).

[12]To depart from a vision where knowledge is reduced to an information-codified form one can

and an explicit part. Interest in tacit knowledge stems from Polanyi's (1956) argument that we frequently know a good deal more than we can express verbally. *Tacit knowledge* refers to a fact of common perception that we are all generally aware of certain objects without being focused on the specificity of them. In that sense the tacit part of knowledge may be called sticky: it is attached to the transmitter of information who can retain some part of the knowledge he created. A classical example of this attribute of knowledge comes from Collins' (1974) account of the building and operating of a new type of laser. Collins reports that only those who worked in the lab where it was discovered, or utilized it for training purpose, could actually build this scientific instrument. His hypothesis for this phenomenon was the high level of tacit knowledge involved in the creation of a new artifact and the personal contacts needed to assimilate the subtleties of the building process. Even one of the most codified knowledge - scientific knowledge - cannot be systematically transferred.

Some works on the economics of R&D and technology transfers (e.g Cohen and Levinthal, 1989; 1990; Rosenberg, 1990) underscore the significance of the tacit elements in technological knowledge, calling attention to the fact that the information contained in patents, blueprints and other codified forms of knowledge are often insufficient for successful implementation of technical innovations. Cohen and Levinthal argue that when learning is difficult, firms may need to make internal investments in order to absorb external knowledge. They argue that "firms may conduct basic research less for particular results than to be able to provide themselves with the general background knowledge" that would help them to exploit technological advances more effectively (1990, p. 148). In that sense a firm's prior relevant R&D helps to build *absorptive capacity*, which they describe as the "ability to recognize the value of external information, assimilate that information, and then apply it to commercial ends." The above elements suggest that depending on the type of knowledge (whether tacit or explicit, individual or collective), its organization of knowledge will be, more or less, open to outsiders. As a consequence, its dissemination and assimilation will be based mainly on internal learning pro-

refer to Ancori et al., (2000) and their references.

cesses (for instance within a firm) or open to the environment.

c. Scientific knowledge, uncertainty and cumulativeness

So far, one of our central arguments is that knowledge production and diffusion, if left to competitive markets, is likely to be suboptimal because of the inability of the producers to fully appropriate the benefits that are created by new knowledge and information. We have now to specify more precisely which kind of knowledge we are focusing on, and what the implications of its suboptimal production and distribution are. As we are mainly interested by university research, we will focus on knowledge derived from science and academic engineering research activities.

We are arguing here that knowledge derived from science and academic engineering research activities has some qualities that make it particularly acute to the problems mentioned so far, and that the costs to the society of knowledge underproduction in these sectors are great. First, the type of knowledge produced by universities is relatively codified. Articles published in scientific journals, conference presentations, books and so on, are highly codified sources of information difficult to confine for private use. It does not imply that we could all use it, but that it would be difficult to exclude other from getting this information. For instance we all know that $E = MC^2$, we can even transmit this piece of knowledge, but only people trained as physicists could exploit and valorize this information. Second, academic research is a particularly uncertain, serendipitous enterprise. The uncertainty is greater when conducting fundamental, exploratory R&D, compared to commercially targeted R&D. In an idealized version, the work of scientists is motivated by a disinterested quest for greater understanding. In addition, new knowledge often comes from successes that would have been difficult to predict. Serendipity is the key here. This unpredictability nature of innovative activity hampers private incentive to allocate resources to it. Due to the non-probabilistic nature of the outcome of the research activity, it is very difficult to know ex-ante the chances of success of research, especially when the research is rather basic. There is, consequently, no possible market to insure all the possible outcomes of the innovative activity, hence the tendency to underinvest in innovative activities.

One way to illustrate this uncertainty is to give a simple theoretical example to help grasp the idea. Let us suppose that a scientist has a collection of N chemical elements and that he wants to test how they interact when mixed together. In such a setting, there would be $2^N - 1$ different concoction of K elements, where K varies between 1 to N. If N is equal to 100, it will result in about 10^{30} different mixtures (there will be even more combinations if we take into account the proportion of which ingredients can be mixed). The different combinations are nearly infinite, even if our scientist would try a different mix every second of his life, he would still be far from exhausting all the solutions. Of course, experience and theories can map out lots of possible inadequate mixes, but potential outcomes are still too numerous.[13] Clearly space for exploration is endless, and outcomes are highly uncertain. Finally, scientific knowledge is a cumulative good: it is not only an output, it is often an input for producing further knowledge. As it is not depleted by usage, it can be used, reused, and rearranged to create new knowledge. It is particularly true in the academic community, where outputs of scientific research are seldom a final product. They have their principal use in further research. Illustrating this tendency is Newton's famous remark "If I have seen farther it is by standing on the shoulders of giants." This quote highlights the cooperative and cumulative quality of scientific achievement. On top of that, it can be argued that the more knowledge you have, the higher the probability that you are going to create new knowledge. This comes from the fact that knowledge can be recomposed in many different ways. In economic terms, this property reveals increasing return in use, which further impedes its production under market conditions. As a concluding remark we refer to Arrow (1962):

> To sum up we expect a free enterprise economy to under invest in research (as compared with an ideal), because it is risky, because the product can be appropriated only to a limited extent and because of increasing returns in use. (ibid., p. 619)

The above developments of the characteristics of knowledge suggest that in the

[13]This example is adapted from Romer (1993, p. 69-70). Commenting on it, he noted that "to appreciate the potential for discovery, one needs only consider the possibility that an extremely small fraction of the large number of possible mixtures may be valuable".

economic sense it is a "good" with special properties. Knowledge is at once an input and an output in the learning process. In many instances, it is produced in a collective process based on cumulative improvements and modifications. Moreover, the research activity, which produces scientific knowledge, is a rather uncertain activity where private incentives are relatively weak. In such a setting, there is room for the argument of requiring alternative mechanisms to the market one in order to promote scientific research, a point we will touch upon in the next section.

1.2.3 Different goals, different types of arrangements

The picture we have drawn so far calls to the deployment of market and non-market institutional mechanisms to resolve the problem of appropriability, and particularly, to encourage the provision of scientific and technical knowledge. In this process one is required to be resourceful, to kill two birds with one stone: it is necessary to increase the incentive to produce scientific knowledge while at same time favoring the distribution and spillover of this knowledge into society. Paul David (1993a) refers to the three principal institutional devices that can be put in place to elicit the production and diffusion of knowledge: "The three P's", standing for state Procurement, public Patronage, and the legal exclusive ownership of intellectual Property.

In the case of state procurement, public authorities get involved directly in the processes of production and distribution, contracting where necessary with private agents to do the work. The objective in this approach is to supply the good without having to charge a price that recovers its costs of production. This arrangement is particularly efficient when it is relatively clear to determine which scientific and technological path are worth pursuing, and when the social cost of setting a price higher than the marginal cost is very high. The argument for such an approach is particularly acute in public health. However, the efficiency of this solution depends on two criteria: first, there is a need for a benevolent social planner who could define a level of investment approaching the social optimum; second this planner needs all the available information about project quality and the ways to achieve results. It is often argued that the closer a country is to the technological frontier in a field, the more difficult it is to design a research project. Fransman (1995) gives a good example about this issue in his account of the Fifth Generation Computer Project, a large scale program devised by the Japanese government in the 80s to develop a totally new kind of computer, allowing Japanese companies to undermine IBM's supremacy. However, in strictly scientific terms, the outputs of the program were meager as the beliefs on what computing was all about were being changed during its realization by breakthroughs in microprocessor technology, making the program's goals rapidly obsolete.

The public patronage framework provides independent producers with subsidies financed by general taxation. It also requires that goods be made available to the public freely or at a nominal charge. For David, the term patronage stands for the institutional arrangement for awarding publicly financed prizes, or research grants, based on the submission of a competitive proposal, as well as other subsidies offered to scientists to conduct their research, in exchange for full disclosure of their findings. Patronage goes hand-in-hand with the pursuit of open scientific inquiries. David (1998; 2004) stresses the connection between patronage and the historical emergence of the institution of "open science". We elaborate more on this in the next section.

The third solution is to create a publicly regulated private monopoly and to allow it to charge customers prices that will yield a normal rate of profit. Different kinds of intellectual property rights (IPRs) can be used to create this monopoly: patent, trade secrets, copyrights, trademarks, and design rights, together with new ones such as database rights. For the purpose of this thesis, we limit ourselves to the analysis of patents,[14] as they play a major role in the analysis of UIR. The dilemma that patents are addressing is as follows: one patent must provide a private agent with the possibility to appropriate enough return on its R&D activities to make the investment worthwhile, while ensuring the necessary dissemination of research results. A patent confers, in theory, perfect appropriability (monopoly

[14]The word patent originates from the Latin *patere*, which means lay open, an abbreviation from the term “letters patent” which simply refer to open letters. It originally denoted an open for public reading of royal decree, hence it carried the seal of the sovereign grantor on the inside, rather than being closed by a seal on the outside.

of the invention) for a limited time in return for a public disclosure that ensures, again in theory, widespread diffusion of benefits when the patent expires. Under this system the concept of priority is central. In order to be awarded a temporary monopoly on his invention an inventor has to prove the originality and novelty of his work.

This system purports to induce the rapid disclosure of new inventions but it comes with one important caveat avoided by patronage and procurement. It entails a restriction in the extent to which applications of the protected knowledge can be developed by permitting the imposition of license and royalty charges on the potential users. This possibility of a reduced usage of the invention is detrimental to society, and to consumers in particular, as new products can be made available by competitors, had they been allowed to market them. This is called a deadweight loss resulting from the monopoly created by the patent, as the allocation of resources is not Pareto optimal.

As David (1993) pointed out: "None of "the three Ps" provides a complete and perfect solution to the problem they all address. Some field of useful employment has been found for each type of institutional arrangement, but no one has emerged as clearly superior to the others in all contexts". In the next section, we describe the "open science" arrangement and its relation to the patronage system. We will resume subsequently on the increasing usage of patents by the academic community.

1.2.4 The open science arrangement

The content of this section draws heavily on the writings of Paul David[15] for the logic behind the emergence of the open science arrangement and the explanations of its working mechanisms, as well as on the seminal contributions of Robert Merton that called attention to the importance of considering science as a social construct, with its norms, values, and organizational characteristics.

[15] Paul David is one of the major proponents of what has come to be called the Stanford school of the economics of science, which encompasses the work of economic historians such as Nathan Rosenberg, Gavin Wright and their students, among others, David Mowery.

a. *The Republic of Science: a Mertonian quest*

A striking phenomenon in the sociology of science is a high degree of mimetic patterns across the different fields of science. Whether in natural, engineering or social sciences, most fields have their academic societies, journals, conferences, public and private grants, peer-review panels of experts for funding committies, and so forth. In this instance, we might refer to a *Republic of Science*, as coined by the physical chemist and philosopher Michael Polanyi (1969) to describe a setting where scientists are freely coordinating their task within a common system:

> The first thing to make clear is that scientists, freely making their own choices of problems and pursuing them in the light of their own personal judgment, are in fact co-operating as a closely knit organization [...] We may call this a co-ordination by mutual adjustment of independent initiatives –of initiatives which are co-ordinated because each takes into accounts all the other initiatives operating within the same system. (Polanyi, 1969, p. 49-50)

Robert Merton (1973) was amazed by the scattered place that the institution of science was holding as a field of inquiry by the social sciences. He subsequently engaged into the quest of deciphering the various arcanes of the scientific world in essays that were gathered in: *The Sociology of Science: Theoretical and Empirical Investigations* (1973).

On a sociological level, we can argue that science is an activity involving social interactions. It is a social construct, where scientists are embedded in particular networks of interactions. It is commonly referred as (1) a set of characteristic methods by which knowledge is certified; (2) a stock of accumulated knowledge; (3) a set of cultural values governing the scientific enquiries; (4) or any combinations of the foregoing (Merton 1973, Ch. 13). Merton envisioned science as governed by series of values and norms, which have emerged progressively through repeated interactions among scientists:

> The ethos of science is that affectively toned complex of values and norms which held to be binding on the man of science. [...] Although the ethos of science has not been codified, it can be inferred from the moral consensus of scientists as expressed in use and wont, in countless writings on the scientific spirit and in moral indignation directed towards contraventions of the ethos. (Merton 1973, p. 268-69)

In examining the ethos of modern science, Merton (1973) defines four sets of institutional imperatives that define the ethos[16] of modern science: Communism, Universalism, Disinterestedness, and Organized Skepticism. The communal ethos emphasizes the cooperative character of the scientific inquiry, stressing that the accumulation of reliable scientific knowledge is a social rather than an individual endeavor. Accordingly, property rights are whittled down to the minimum, in exchange for recognition and esteem by peers. The products of the scientific competition are communized, and esteem accrues to the producer of knowledge. Therefore, the concern over priority and originality becomes central in the history of modern science. Scientists' intellectual achievements are indeed judged by their peers on how they have contributed to solve scientific problems considered as worthwhile by the community. "Secrecy is the antithesis of this norm; full and open communication its enactment" (ibid, p. 274). This need to be recognized as the first is not linked to a somewhat egocentric propensity of the researchers, but rather to the subsequent rewards that are attached to the scientific activity. Priority gives access to the "golden book of first" (ibid, p. 645), and the attached rewards such as: eponymy of the discovery (e.g., Newtonian epoch; Comte, the father of sociology, Boolean algebra, etc.), prizes, medals, honorary degrees, etc. These rewards are largely honorific as the pursuit of science is culturally defined as being primarily a disinterested search for truth. The disinterestedness of the member of the scientific profession is another important element of the scientific ethos, although this attribute does not originate from unusually high level of moral integrity. It is rather a necessity of the system: new knowledge should not be of such personal interest to the researcher as to impede its availability, or to influence co-workers' views as reviewing peers. Therefore research agendas should be in the hands of disinterested agents or organizations. Scientific claims are to be evaluated in terms of pre-established impersonal criteria, hence not depending on such fraudulent criteria as gender, race, age, religion or nationality. The force of this uni-

[16] "The ethos of science refers to an emotionally toned complex of rules, prescriptions, mores, beliefs, values and presupposition which are held to be binding upon the scientist. [. . .] Transgression is curbed by internal prohibitions and by disproving emotional reactions which are mobilized by the supporters of the ethos" Merton (1973, p. 258)

versalist norm is to allow entry to all talented individuals regardless of personal or social attributes. Free access to scientific pursuit is a functional imperative. Finally, organized skepticism is at the center of the research process: scientists question results, establish routines, and authority. There is no unqualified faith, consequently making skepticism a virtue. All new scientific claims that ought to be added to the stock of reliable knowledge will have to be subjected to trials of verification, without insult to the claimant.

The Mertonian norms of science are often referred to by the acronym CUDOS.[17] To make up the O, Originality is often added as a defining element to the ethos of science: "emphasis upon originality on the institutional plane" (Merton, 1957, p. 640), is an essential element of the organization of science. A scientist needs "the recognition by others of the scientist's distinctive part in having brought the result into being" (ibid., p. 640). One can argue that this recognition is a peculiar kind of property right. Linked to this is the institutional norm of humility, or "the practice of acknowledging the heavy indebtedness to the legacy of the knowledge bequeathed by predecessors" (ibid., p. 646).

In short review, we may interpret the above elements as follows. The work of Merton has emphasized that the reward structure of science elicits compliance, even from the reluctant, with the norms of openness which is a logical implication of CUDOS : speedy disclosure of new findings, recognition of one's contribution to the creation of reliable knowledge and consequent collegial reputation, verification, application and extension of research findings by colleagues and peers. All these may seem natural, but it is actually quite a comparatively recent innovation by historical standards. The next section deals with historical elements that permitted such an institutional arrangement to bloom.

b. Emergence of the phenomenon

Paul David refers to *open science* as "activities supported by the state funding, the patronage of private foundations and carried on today in universities and public (not-for-profit) institutes" (David, 1998, p.15). In his view, open science is quite a

[17] The word Kudos comes from Greek, it means glory.

recent social construct. He traces the origin of the phenomenon back to the 17th and 18th centuries, and puts it in stark contrast with the previous ethos of secrecy in the pursuit of nature's secrets, as epitomized by the traditions of alchemy. He argues that competition among noble patrons in their use of prestigious clients (scientists) had a decisive influence upon the historical formation of the key elements of open science. Frederico Cesi, a noble patron and scientist, created the Accademia dei Linci, the first academy of science in Italy; the Academia del Cimento in Italy was founded in 1657 and sponsored by two Medici; the Royal Society of London was granted a Royal Charter by King Charles II in 1660; the Académie des Sciences was instituted in 1666 by Louis XIV at the suggestion of Jean-Baptiste Colbert. All these historical examples illustrate the intense competition by noble patrons to sponsor philosophers and savants of great renown. It can be argued that this rivalry was the legacy of western European feudalism. Deprived of central power, noble patrons were competing for prestigious clients. Kings and princes, people in positions of power more generally were eager to be surrounded by poets, artists, natural philosophers, instrument-makers, and the like, not only for their pleasant company, but also to reinforce claims to status and prestige. Two kinds of motivation are reflected in this patronage's system: the *utilitarian* and the *ornamental*. Most rulers recognized the need in their court for men capable of producing new ideas and inventions to solve problems connected to medicine, warfare, food production, engineering, and so forth. But if they were to be useful, inventions and discoveries that met these goals would have to be, at least partially, kept secret. For instance, maps concerning trade routes were concealed from the public eye, and military devices were best kept secret from rivals. The reason for the emergence of cooperative inquiry and free sharing of knowledge among scientists is to be found in the second rational for patronage, the ornamental.

In the pursuit of ornamental goals, it was rational for the patron to widely publicize spectacular discoveries and creations. It was in the interest of the patron to encourage the wide diffusion of his clients' findings, for their fame augmented their own. But an element came, that complicated the task of the patrons while competing to attract the most talented men of knowledge. During the 16th century, the rise of algebra, geometry and trigonometry by natural philosophers and others, made their discoveries less readily assimilable to their potential patron. It is easier to pass judgement, right or wrong, in choosing a court composer than having a thorough appraisal of a mathematical treaty. This created a common agency problem, as there was an increasing asymmetry of information between principal-patron and their mathematically inclined agent-clients. There was no way for the patron to assess the quality of the work produced, and therefore it put them at great risk of embarrassment in case they had sponsored a fraud, or worse a heretic. This has created compelling reasons for patrons to delegate responsibilities for evaluating and selecting among savants. The scientists had to organize the production of trustworthy testimonials to their own credibility and their works, leading to the creation of scientific societies, prizes, epistolary exchanges among scientists, and so on. Through of a network of correspondence and the emergence of *invisible colleges*[18] among scientists, collegiate reputation of scientists could be both secured and widely advertised. On top of that, the competition among incompletely informed principals for the services of multiple agents results in favorable contract terms for the scientists, especially in terms of autonomy and financial support. In the words of David (1998, p. 20):

> The norm of cooperation and information disclosure within the community of scientists, and their institutionalization through the activities of formal scientific organizations, emerged (in part at least) as a response to informational requirements of a system of patronage in which the competition among noble patrons for prestigious clients was crucial.

c. *Economic justifications of the open science regime*

As we have depicted so far the "Republic of Science" is an institutional arrangement with an essential collective character, based on an ethos of cooperative inquiry and the free sharing of results. Its comparative efficiency lies in the advantage of open inquiry and complete disclosure of research findings and methods as a basis for the cooperative, cumulative generation of reliable additions to the

[18]Price (1963) had extended Robert Boyle' s seventeenth-century term "invisible college" to designate the informal clusters of scientists collaborating at newly developing research frontiers, these groups being generally limited to a size that can be handled by interpersonal relationships.

stock of knowledge. The openness reduces the excess duplication of research efforts, while wide sharing of information puts knowledge in the hands of scientists who put them to use. This has the effect of enlarging the domain of complementarity among additions to the stock of knowledge, and promote positive spillovers among distinct research programs.

Dasgupta and David (1994) argued that the open science arrangement has two fundamental and original economic properties that contribute to its efficiency. First, scientists are those most able to carry out validation and evaluation of their work in peer-review procedures. They are themselves setting research agendas and evaluating each other's works, hence avoiding principal-agent problems between funding agencies and the research community. Secondly, since it is the very action of disclosing knowledge that induces the rewards, it creates simultaneous incentives for both knowledge creation and its broad dissemination within the community. On top of that, treating new findings as part of the public domain fully exploits the public goods properties that permit data and information to be concurrently shared in use and re-used indefinitely, promoting faster growth of the knowledge stock.

Throughout the thesis, as a stylized working model, we associate university science with the elements we have defined so far as portraying an openness framework of communication and the Republic of Science. The economic rationale of this system is to treat new findings as public goods and favor their production to promote a steady growth of the reliable stock of knowledge. This process is in sharp contrast with a social organization which is directed towards the maximization of wealth stock through the creation of economic rents from data, information and knowledge by means of secrecy or intellectual property rights. Following Dasgupta and David (1994), we refer to the community of researchers engaged in proprietary scientific pursuit as forming the "Realm of Technology".

1.2.5 Making a place for the industry

We are now turning our attention to the industry side of the university-industry relationship. For the purpose of our inquiry let us lay down salient differences between university and industrial science. Following Dasgupta and David (1987), we argue that the scientific community appears to be concerned with the stock of reliable knowledge and is devoted to furthering its growth, while the industrial community, operating in a proprietary research regime, is concerned with the private returns or economic rents that can be earned from that stock. Harvesting these rents requires a control of the knowledge produced through secrecy or exclusive possession of the rights to its commercial use, as unlimited entry of competing users could seriously hamper the profitability of investing in R&D.

Each community has institutional mechanisms and norms that persuade researchers to follow research procedures that tend to further its particular goals. As we have seen so far, university researchers favor the fast dissemination of research results throughout the research community, whereas technology researchers, who are free to adopt information strategies ranging from full disclosure to total secrecy, do not share this tendency. The Realm of Technology produces knowledge for economic ends and focuses on private appropriation through patents or other modes of protection. In terms of ethos, CUDOS is not internalized by industrial scientists. Ziman (2000) proposes another acronym to define what he calls *industrial science*, as opposed to *academic science*, as Proprietary, Local, Authoritarian, Commissioned and Expert (PLACE). Industrial science produces proprietary knowledge that is not necessarily made public. It focuses on local technical problems rather than on general understanding. Industrial scientists conduct research under managerial authority rather than as autonomous individuals. Their research is commissioned to achieve commercial goals. Researchers are employed as expert problem solvers who should work on company problems, rather than for their personal creativity as such. He spells out these attributes of PLACE and puts it in contradiction with the Mertonian norms. It can be argued that the epistemology of science is linked to its sociology mainly at the level of research practice. Scientists produce knowledge according to the norms and principles that apply to their situation. In this way, the industrial and academic spheres operate under different regulating mechanisms[19].

[19]The development of the concept of PLACE is less elaborated here than the one of CUDOS as it is not as developed and articulated in the original text. However, we feel that its use enables a conceptual distinction between university and industrial science. Particularly for our interest, it

Understanding how science is conducted at the intersection of the university and industrial spheres can help us pinpoint whether and how norms are evolving through the interaction between these two spheres ruled by antagonist practices. As science organization is a complex system responding opportunistically to changing circumstances, we argue that these changes are the product of expediency, not design. We intend to investigate the effect that industrial collaborations have on the way academic researchers organize their work.

1.2.6 University-Industry relation

> History shows that almost every scientific discovery, which has ultimately revolutionized methods of industry, has been made in the pursuit of knowledge for its own sake, without direct aim at the attainment of any particular practical advantage: universities are the proper places for such pursuit of "pure science" and for the establishment of laboratories, etc., devoted to it. (Marshall, 1920)

a. Rational

The idea underlying the theoretical development that we wish to put forward is the following: we distinguish between two distinctive organizational regimes, university and industrial science, which serve quite different and potentially complementary societal purposes. As opined by David (1993b) neither system can perform effectively alone over the long term as their specific capabilities and limitations are complementary. It is therefore important to maintain them in a productive balance. As Marshall hints in the quote above, the idea that organizational complementarities are not pristine, the pursuit of "pure science" often leads to the discovery of new industrial methods. This kind of investigation may increase the rate of return of private investment in innovation. Fundamental knowledge and tools developed in the pursuit of basic science can provide guidance for applied researchers as where to search and where it will be futile to look. The physicist and historian of science, Gerald Holton, remarked that if scientists in the field of photoelectricity would have to display a label stating their origin, they would list

implies that the industrialization of academic science has the potential of establishing a number of practices that are essentially foreign to its culture.

prominently "Einstein, Annalen der Physik 17 (1905), pp. 132-148."[20] This idea is developed by Fleming and Sorenson (2004) who argue that science acts as a map providing inventors with a sense of the underlying technological landscape they are involved in. This has the effect of guiding private research in the direction of the most promising technological venues by leading inventors directly to useful combinations of knowledge and diminishing the probability of engaging in fruitless paths of research. The understanding of scientific knowledge provides researchers with a search map that decreases the variability of outcomes.[21] Anecdotally, in the same vein, the industrialist Andrew Carnegie stressed the benefits of scientific knowledge while noting that "nine-tenths of all the uncertainties of pig iron making were dispelled under the burning sun of chemical knowledge" (Rosenberg, 1985).

That said, one question remains: why is it particularly important to understand the relation between these two regimes? One relevant answer could be that as countries progressively move towards knowledge-based economies, universities are increasingly asked to contribute to the creation of new knowledge in order to help companies to produce innovation. This leads us to envision a potential division of labor between the two entities that can increase the efficiency of the overall system, as the two systems exhibit complementarities and focus on different elements in the search process. In a theoretical paper, Aghion et al. (2008) develop a model that highlight the potential complementarities between academic and industrial research. They focus on one element that we have stressed so far, namely the ability of academic scientists to freely pursue their own interests. They see this element as a fundamental difference between academia and the private sector. In a sequential innovation process, their analysis reveals that academia has a comparative advantage in early-stage research as scientists can freely choose which project to focus on, even if the probability of success is low. At the same time, the private sector's ability to direct scientists towards higher-payoff activities makes it more attractive for later-stage research. This analysis, though interesting, is necessarily

[20] As cited in David (1993b).

[21] A vivid illustration of the interplay between science and technology in defining a search space can be found in Fleming's (2002) account on the creation of the thermal ink-jet.

reductivist in scope and call for a more detail account the phenomena behind these hypotheses. In-depth analysis has to be conducted to get a clearer picture of the mechanisms behind UIR. In the next section, we consider this increasing use of science by companies.

b. Increasing use of science by the industry

Successful innovation by a firm partly depends on its ability to acquire technical knowledge from external sources and effectively integrate them in its innovative activities. There are reasons to believe that the need for firms to access to external sources of knowledge is on the rise, one of those sources of external knowledge is universities, especially in science-based industries where relationships to scientific knowledge are frequent. Universities have long served as a source of scientific and technical knowledge; however, the discovery of breakthroughs with significant commercial potential in biotechnology, computer science, materials science, and nanotechnology is driving increased industry sponsorship and use of university research. The use of university research results by firms can be in the form of "ready to use" technologies (Colyvas et al., 2002) or in many instances is more of an exploratory nature (Bercovitz and Feldman, 2007). The aim of this section is to emphasize the growing application of science in some industrial fields, mainly in science-based sectors.[22] Based on this premise, we first consider the ability of a firm to assimilate externally generated scientific knowledge, then present some studies showing the influence of public science on industrial innovation, and finally stress the importance of the maturity of a scientific field in shaping UIR.

Cohen and Levinthal (1989; 1990) introduced the concept of “absorptive capacity”[23] referring to a firm’s ability to utilize outside knowledge efficiently. They argued that this capacity is a function of the firm’s own investment in R&D. While firms clearly focus on research that promises financial returns, some firms also devote resources to basic research because it may increase their ability to absorb external knowledge (Rosenberg, 1990). In a study on drug discovery, Cockburn and

[22]Science-based fields are often defined as fields with frequent reference to scientific knowledge.

[23]The concept refers to a firm’s ability to recognize, assimilate, and apply new scientific information for its innovation and product development.

Henderson (1998) analyzed the related concept of "*connectedness*" by which firms may increase their internal capacity through contacts with the open science community, engaged with sharing research results through collaborations outside the firm. The concept of connectedness expresses the degree to which a firm's scientists are connected to their counterparts outside the firm. Using regression models, they showed a positive relation between connectedness and research productivity. They hypothesize that the ability to interact and access public sector activity may be an important determinant of the productivity of downstream private research. Lim (2006) combines the above two concepts and argues that the absorptive capacity of firms is primarily a function of its connectedness, of which its investment in R&D is just one of several components. He convincingly argues that in order to develop disciplinary absorptive capacity (general scientific knowledge), a firm should encourage its researchers to be active participants in the scientific community in order to monitor new knowledge and talent while protecting the domain of specific knowledge (solution to a specific technical problem) they create.

A way to appreciate the increasing importance of science for the industry is to give some selected figures. Meyer-Krahmer and Schmoch (1998) indicated that the total share of industrial funding within the total research budget of German universities has increased from 5 to 9% (1985-1995). At the same time they estimated the industrial share in the engineering sciences at an average level of about 20%. In an often quoted study based on data from 76 firms (1975-1985), Mansfield (1995) found that about 11% of their new products and 9% of the processes could not have been developed in the absence of recent academic research (less than 15). Using citation linkage between US patents and scientific research papers to visualize the link between industrial and academic science, Narin et al. (1997b) found that firms rely quite heavily on publicly funded research as a source of new ideas or technological knowledge.[24] Survey data shows a similar trend, for America both the Yale (1983) and the Carnegie Mellon Survey (1994) on R&D have shown the importance of university research for industrial innovation (Cohen, et al., 2002).

[24]The paper of Jaffe (1989) is generally acknowledge to have laid the groundwork for evaluating the influence of university research using patent documents.

Using the PACE[25] survey of Europe's largest firms, Arundel and Geuna (2004) demonstrate that public science is among the most important sources of technological knowledge for the innovative activities of Europe's largest industrial firms. Moreover, universities are creating new instruments and methodologies that industries are using. Rosenberg (1992) stresses the strategic importance of scientific instruments in many industries such as semiconductor or biotechnology: "Indeed much, perhaps most, of the equipment that one sees today in an up-to-date electronics manufacturing plant had its origin in the university research laboratory" (ibid., p. 384). There are many historical examples where a instrumentation that was developed in the pursuit of scientific knowledge eventually had many applications as part of the manufacturing process.

In the daybreak of a scientific field, university and public research scientists are more involved in the development of the technological properties of their discoveries. For instance, in the beginning of applied genetics in the mid-1970s, faculty and public researchers implication in the commercialization of biological research was important.[26] In the domain of biotechnology, Krimsky et al. (1991) showed in a study covering the 1985-88 period that academic scientists actively participated in the commercialization of genetics research by establishing formal associations with many of the new biotechnology companies. They looked at the composition of the Scientific advisory board and found that 31.1% of faculty of MIT's department of biology (N=74) were sitting on the Scientific Advisory Board of a biotech company. For Harvard biomedical faculty the number is 19.5% (N=156). This finding shows how the involvement of university scientists in shaping the research agenda of these firms, while being involved in the research agenda of the open community. Using interviews of more than 80 US scientists in the field of life science, Owen-Smith and Powell (2001) found that novel research technologies bring basic research and product development closer. In the case of microelectronics, where universities are collaborating with the industry to define their research strategy, high scientific performance in research teams is linked to a strong connection with the researchers from the two spheres. (Balconi and Laboranti, 2006). More

[25] Policies, Appropriation and Competitiveness in Europe (PACE).

[26] For a vivid history of the rise of the nascent biotechnology industry see Chandler (2005).

generally, the rise of scientific disciplines with plentiful industrial applications, such as molecular biology, has generated interests in the industrial community for university research and new opportunities for the academic community to shape industrial developments.

1.2.7 Contact, evolution, adaptation

One might expect that by conducting research at the interface of academia and industry, the actors of the two communities might engage in practices that become more alike. For instance, one might presume that firms will exert strong efforts to prevent their technology from going public, which is the case in many instances. But in some cases they take actions to make their proprietary knowledge available to others. At the other end, university scientists are in most cases used to freely diffusing their findings, but the rise of IPRs uses by universities is an element hinging against this tendency. What we want to argue here is that under some conditions, contrarily to traditional practices in their respective communities, industrial scientists might have some motivations to freely communicate and share their results, while academic researchers facing commercialization pressures and opportunities may delay or alter the publication of their results.

a. Collective invention

We highlighted that in the open science setting, the rapid divulgation of research results to the whole community is a fundamental piece of the system as it facilitates the collective resolution of scientific problems and the creation of reliable knowledge. Despite the emphasis on proprietary knowledge, there are circumstances when industrial science may reveal information voluntarily, without strings attached. In that case we will refer to the concept of *open knowledge disclosure*. This concept refers to a situation where a firm voluntarily decides to reveal some of its knowledge to other firms without receiving a direct compensation, abandoning the possibility to exclude any firm to access this knowledge (Pénin, 2007). This phenomenon is not a new one. Using historical accounts of the nineteenth-century English blast furnace industry, Allen (1983) stressed that some innovators publicly revealed data on their furnace design and performance in professional society meetings and in published communications. He describes these behaviors as being part of a "collective innovation" process. In a more recent context, Henderson and colleagues (Cockburn and Henderson, 1998; Henderson, et al., 1999) highlight the increased publication of results by some firms. A firm has various reasons to adopt such a behavior of open knowledge disclosure. Among others we can cite the difficulty of keeping information secret, setting standards, easing cooperation among competitors, the existence of pecuniary spillovers, reputation, and increasing the motivation of researchers. Although companies may reveal and publish some of their research results for a large variety of reasons, the one we are the most interested in is the leveraging of results as an interface to the global research community. The rest of the section will concentrate on this aspect as it is a crucial element in the university-industry dynamic. Indeed, industrial scientists have many reasons to build up their reputation in the scientific community, this can be done through publishing their research findings as a way to engage cooperation with academics and in turn this publication of research results may be a way for the companies to attract talented researchers and provide them with non-monetary motivations.

First, open knowledge disclosure may help to signal a firm's competences to potential partners but also to access technical opportunities produced by the scientific community. Nelson (1990) argues that firms have many good reasons to publish selected results of their research activity of relatively low competitive value in order to maximize visibility and link up to the scientific community. In the same vein, Hicks (1995) points out that the corporate research papers in the open literature may also signal R&D capabilities to (potential) partners, and that entering the circle of publication-inclined organizations may be used as a currency of exchange to enter the academic community. The essence of this argument can be found in a statement by a past group vice president for corporate research at Xerox:

> In order for industrial research organisations to be in close contact with new advances in basic science, it is important for the industrial group to be an active participant at the leading edge of world science. Effective technical interchange requires that the industrial organisation have its own basic research

> results in the relevant scientific area to use as the currency of exchange. (Hicks, 1995, p. 420)

The main point here is that publications may be viewed as a barter to enter the network of academic science. In order to obtain access to the scientific commons, it is critical to enter into the give and take relationships that characterize the scientific community. In that view the results of interviews conducted by Cockburn and Henderson (1998) corroborate this point : "Our respondents suggested that a firm's researchers need to be active participants in the construction of publicly available research results, despite the issues of appropriability that such active collaboration raises". On top of that, Hicks (1995) defends the idea that publications signal the existence of tacit knowledge and other non publishable resources, thus building the credibility needed to find partners for knowledge exchange. This strategy might in some cases have more direct pay-offs. In a series of papers centered on the biotechnology industry, Lynne Zucker and her colleagues have shown that collaborations between university "star" scientists - according to their outstanding research productivity - and firms have a large positive impact on firms' research productivity (Zucker and Darby, 2001; Zucker, et al., 2002; Zucker, et al., 1998).

Second, scientists, even in corporations, often take pride in their ability to conduct good science. A story about a manager at Hewlett-Packard illustrates this penchant for science: "Even though he had a Master's degree in electrical engineering and business administration and managed a laboratory of almost 100 professionals, he was still most proud when he could do 'good' physics"(Fleming, 2002). More generally, scientists derive satisfactions from solving scientific puzzles[27] and are eager to win scientific competitions (Stephan and Levin 1992). Industrial scientists and engineers, like academics, take pride in their professional work and reputation, which to a considerable extend is shaped by publications and participation in conferences. In that respect, letting industrial scientists publish their results in journals may improve their productivity. Gambardella (1992) noted that

[27]We could even go a step further following the phrasing of the historian of science Robert Hull "The wow-feeling of discovery, whether it turns out to be veridical or not, is exhilarating. Like orgasm, it is something anyone who has experienced it wants to experience again -as often as possible."(As cited in Stephan, et al., 2007)

successful pharmaceutical firms are like academic departments, offering their scientists autonomy to choose research projects and publish their work. However, a science-oriented research environment could also be a reward for researchers in lieu of better compensation (Stern, 2004). Stern finds that wages, paid according to scientific ability, are substantially lower in jobs that promise scientists either some freedom to pursue their own individual research agendas, or that encourage the publication of this work. On top of that, this has the indirect advantage of favoring relations with the academic world.

b. Proprietary knowledge in academic science

"The idea of the university as an active force in firm formation and regional economic development has spread widely [. . .] throughout the U.S. and worldwide." Charles M. Vest, the president of the Massachusetts Institute of Technology (MIT), said that Boston's universities were preparing to nurture the next round of entrepreneurship in their region.[28] This element is heralded in many essays written by Henry Etzkowitz and colleagues[29] who claim that we are in an era where the rise of the entrepreneurial university can be foreseen, MIT being a typical example of the phenomenon. The Triple Helix thesis postulates that the interaction between university, industry, and government is the key to improving the conditions for innovation in a knowledge-based society.

In accordance with this climate, universities are increasingly commercializing their discoveries. A consequence of this trend is the increasing involvement of universities in the creation and management of IPRs. A major symbol of this trend is the legislative frenzy that started with the US Bayh-Dole Act (BD) in 1980, and went through subsequent similar provisions in Europe and Japan.[30] The Act allowed universities to claim title to inventions made as a result of federally funded research.[31] The congressional motivation in passing BD originated from the propo-

[28] As cited in Blumenthal (2003).

[29] One can refer to Etzkowitz and Leydesdorff (1997; 2000) for a overview of the Triple-Helix concept.

[30] For more details about academic patents in Europe one can refer to Verspagen (2006), and for the Japanese context to Takahashi and Carraz (2009).

[31] For an unabridged account of the BD Act one can refer to Mowery et al. (2004); a critical review

sition that patents resulting from federally funded research were unexploited due to insecurity regarding their ownership. It assumed that restrictions on dissemination of the results of university discoveries, through university ownership of faculty inventions, would enhance economic efficiency by supporting their commercialization. Therefore, creating an increasing pressure to translate the results of their work into privately appropriable knowledge. In that sense it collides with the free diffusion of research results, a crucial element of the ethos of open-academic science. We do not intend here to reopen the academic Pandora's box of debates relating to the BD Act, rather we want to stress that the changes in legal conditions and technological opportunities, notably fueled by the emergence of the biotechnology industry in the 1980s, have created an environment favorable to an increasing use of patents by academic researchers. As a result, we are interested in analyzing how these new circumstances influence the organizational arrangement of academic science.

Indeed, the fencing of the research commons is not without potential dangers for the organization of the academic world. In an editorial in *Science* (2002), Donald Kennedy, former president of Stanford University and ex-editor-in-chief of *Science*, proposed a metaphor between the Great Enclosure of the 19th-century American West and the great shift in basic biomedical science towards the private sector. They both brought huge private capital in the process, but at the same time they have brought back problems. "The contemporary enclosure of the Endless frontier" is yielding patent dispute,[32] conflict of interest, new problems of licensing and royalty distribution policies. A potential negative effect of increased university patenting and licensing is the weakening of researchers' allegiance to the Republic of Science. Below are some of the related concerns raised in the literature:

- Unwillingness to share research materials (Blumenthal, et al., 1997; Campbell, et al., 2002; Louis, et al., 2001; Walsh, et al., 2005);
- Publications delays (Blumenthal, et al., 1997; Gotzsche, et al., 2006; Zhen, et al., 2009);

on the economic efficiency of the Act can be found in Kenney and Patton (2009).

[32] On the undermined experimental use exception by universities see Eisenberg (2003).

- Conflicts of interest resulting in biased research results (Bekelman, et al., 2003);

- Move from basic research to more applied part of the research spectrum (Cohen, et al., 1998; Henderson, et al., 1998);

- And even fraud, especially in biomedical related fields (Ross, et al., 2008).

The community, however, is trying to prevent what it regards as negative in the privatization of commons. For instance, in a detailed account, Rudy et al. (2007) describe the ambivalent reaction by the academic community to a $25 million contract between the "entire" University of Berkeley Plant and Microbial Biology department and Novartis. One of the main fears related to the agreement was that Novartis might then influence the direction of research of a university department. Even if this fear did not materialized, the agreement spurred an intense controversy.

This section of the chapter served to introduce many important concepts and terms we will mobilize throughout the thesis. We have notably pinpointed the characteristics that make knowledge a special commodity, particularly scientific and technological knowledge. Especially in our interest, we have shown that it is both an input and output in the learning process and as such it is not destroyed when it is used. Rather, the opposite happens: it is a cumulative and collective good, which spills over in the vicinity of its usage, making it difficult to appropriate fully. As a result, some mechanisms have been put in place through time to foster its production and diffusion, one of those is the open science arrangement. At the core of this arrangement is the free and open diffusion of research results that are evaluated and validated by peer-review mechanisms. However, this arrangement, especially in the academic community, faces new challenges and opportunities that arose from increase connections with industry and the attention put on technology transfer activities. We address these issues in the remaining of this chapter and more generally in the rest of the thesis.

1.3 Empirical evidences on academic patenting

So far we have examined the theoretical foundations of university-industry differences in conducting research, stressing the mutual influence entailed by research collaborations. We shall now dive into the empirical literature to evaluate how collaborations with industrial researchers affect academic science. We build our analysis on the empirical literature on the research relationship between university and industry, which has been growing steadily over the last twenty years. In order to better grasp this trend we look at the number of publications with a title including both industry and university in a leading bibliometric database.[33] The search results are presented in Figure 1.1. In terms of raw number of publications, it has steadily increased throughout the period (1975-2009), from a few articles a year to 15-30.[34]. The overall aggregate for the period is 251 articles with a total of 1,955 subsequent citations of these works. The interest on the field expanded steadily throughout the period, an indicator being the citations to these works, which have seen a steep continuous rise from 2001 to 2008. The most prolific journal on the subject is *Research Policy*, a journal publishing an important share of the publications we used in this chapter.

In the present section, we shall focus on quantifying the effects of scientific involvement with industry. In order to find a trace of industrial involvement by academics, one can look at the different knowledge transfer mechanisms that an academic may engage in to fraternize with industrialists. What are they exactly? In their seminal work, Rosenberg and Nelson (1994) documented the long tradition of universities transferring knowledge and technology to firms, though this has mainly occurred through channels like publication, conferences, and personal contacts. In terms of technology transfer mechanisms, we can list numerous channels. First, there are the traditional publication and conference channels. Along

[33]The search was performed on the 01/05/2010 using the following instruction in the ISI Web of Science database: Title=(universit* and industr*), refined by: Document Type=(article OR proceedings paper) AND Subject Areas=(management OR business OR economics OR social sciences OR interdisciplinary OR sociology) AND Timespan=1975-2009.

[34]During the same period the number of published papers doubled, in 1990 nearly 690,000 journal articles were produced worldwide while around 1.4 million papers were published in 2008. *Source*: Thomson Reuters Web of Science.

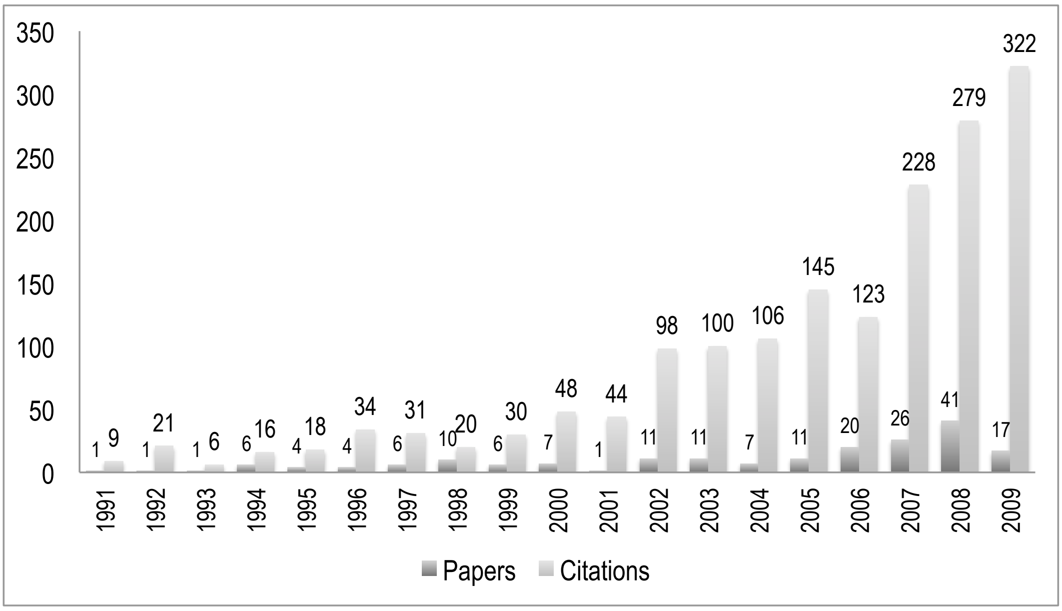

Figure 1.1: University-Industry related publications and citations

with patents they are codified inputs to industrial innovation. Another channel is personal contacts and collaborations. They can take the form of consulting, collaborative or sponsored research, along with informal contacts. Next is the employment of university researchers or students, described as an effective way to transfer knowledge from universities to firms. However, data on personal contacts is difficult to visualize and information on research contracts is difficult to obtain.

Therefore, a majority of the studies we refer to mobilize data on patents, publications and citations. This data combine two advantages: representativeness and availability. In our view, publications and patents symbolize, albeit imperfectly, the desired outcomes of university and industrial researchers. On one hand, the publication of scientific papers is the output of research per excellence in academic science organizations. An historic example portrays this remarkably. In the laboratory of Michael Faraday, the great scientist of the 19th century, the sign “Work, Finish, Publish” hung on the wall (David, 1994). Even today, every scientist's career hangs on the phrase “publish or perish”. On the other hand, patenting is more associated with industrial research. Patent and publication data are more readily available in digital format, which facilitates their extraction and treatment. Their wide availability is one of the reasons for the flowering of many econometric studies utilizing them to investigate the interaction between university and industrial science.

In what follows, we first briefly introduce the notion of patenting in academia (section 1.3.1). We then move on to examine the issue between secrecy and academic patenting (1.3.2), and inspect whether patent and publications are complementing each other (1.3.3). Finally, in section 1.3.4, we investigate the anti-common hypothesis, and in section 1.3.5 the potential decline of academic patents quality. We choose to develop these themes centered on academic patenting as they play a central part in the empirical strategy of this thesis. This relatively new element in the toolbox of an academic has the double advantage of being relatively easy to mobilize in an empirical setting while at the same time being related in its usage by academics with elements such as the definition of the research agenda, diffusion of knowledge, or the productivity of academics.

1.3.1 A few words on patents and academia

The main tools of IP rights are patents, copyrights, trademarks and trade secrets. Concisely, patents require novelty, copyrights necessitate originality, trade secrets mandate confidentiality, and trademark compel identity. In the case of university-industry relationships, patents are the one calling most attention.

In order to be awarded a patent an inventor has to demonstrate three statuary criteria: (1) usefulness; (b) novelty; and (c) nonobiousness. In the case of the US, patentability has been extended throughout the course of time: mathematical algorithms, business processes, and genetically modified organisms are in fact patentable. Altogether evidence shows the intensification of the patenting regime (Jaffe and Lerner, 2004), and universities are not left behind in that trend. In the last thirty years, a radical increase in the number and share of academic patents has been noticed first in the US, then in Europe and more recently in Japan (Mowery et al. 2001; Geuna and Nesta 2006; Takahashi and Carraz 2009). Between 1969 and 1986, universities owned 1.1% of US patents issued, by 1999 that number had risen to 4.8% (Eisenberg, 2003). In Europe, the share of public research institutions' filings (including universities) in total patent applications at the European Patent Office has jumped from about 0.5% in 1981 up to nearly 4% in the early 2000s (Zeebroeck, et al., 2008). In any case, it must be kept in mind that these figures are lower-bound measures, as many university-invented patents are assigned to non-academic institutions. These figures, which make plain the increasing use of patents by academics, call for an appraisal of the influence of patents on university research.

The three main questions we intend to address are (a) whether the expansion of the patenting culture undermines the culture of open science; (b) whether this is delaying and diverting research results, especially in the basic research areas, and finally (c) whether academic patentees are becoming more alike to their corporate peers?

1.3.2 The secrecy issue and academic patenting

One concern over academic patenting is that it may turn the academic open culture into a rather closed one. Indeed, patenting requires novelty and thus secrecy prior to the filing date, which can hinder the dissemination and access to information. For instance, some publications may be delayed or swept under the carpet because of requests from firms to keep information (temporarily) confidential, at least until a patent is granted.[35] There is evidence backing such claims. Blumenthal et al. (1997) found that 19.8% of a sample of US academic life scientists had withheld research results for more than 6 months due to intellectual property rights discussions, patent applications, etc. In a survey of executives of biomedical companies, more than half admitted that their research agreements with universities included restrictions on results communication (Blumenthal, et al., 1996). Based on evidence from the United-Kingdom (UK), Webster and Packer (1997) argue that academic researchers "have become much more strategic in their choice of what information to disclose in their publications to avoid the possibility of

[35] In Chapter 3, we will investigate this issue more practically with survey results for Tohoku University. Though, without further ado we can say that we found that publications were delayed by patent considerations, albeit only for a short period.

a future patent application being compromised".[36] Patenting definitely entered the picture of the publication process. Nevertheless, one can wonder whether the perceived increased use of secrecy is only related to patent consideration. Indeed academic science is built on two contradictory foundations, openness and secrecy. The priority recognition reward system gives incentives to the scientists to share their scientific finding. However, because recognition depends on priority, under considerable strain scientists may deviate from the mores of science, secrecy being one of the issues to relieve stress from competition. As Merton put it:

> The culture of science is, in this measure, pathogenic. It can lead scientists to develop an extreme concern with recognition. [...] Contentiousness, self-assertive claims, secretiveness lest one be forestalled [...] all these have appeared in the history of science and can be thought of as deviant behavior in response to a discrepancy between the enormous emphasis in the culture of science upon original discovery and the actual difficulty many scientists experience in making an original discovery. In this situation of stress, all manners of adaptive behaviors are called into play. (Merton 1973, p. 323)

Mitroff (1974) uses the terms "norms" and "conter-norms" to describe these antagonistic pressures on scientific behavior, thus to be the first it may be rational to remain secretive until the publication of results in spite of the norms of openness. Different institutional contexts are likely to shift researchers values along these two tectonic plates, the question being: is patenting one of those value changers?

Hong and Walsh (2009) tested empirically two phenomena: whether secrecy is increasing in academic science and whether it is driven by commercialization and/or academic competition. Using survey results from 1966 and 1998, they tested the changes in subjects' responses. As a result, they found that secrecy has increased during that period. They noticed a substantial increase in the field of experimental biology. The increase is in absolute terms, as well as compared to mathematics and physics. They showed that scientific competition is the predominant factor contributing to secretive behavior, even amongst experimental biologists. This is in line with the finding of Campbell et al. (2002) in biomedical research. As for the funding involved, Hong and Walsh found a positive relation between industry funding and secrecy. In contrast, collaborating with industrial partners is

[36] As cited in Geuna and Nesta (2006, p.797).

associated with less secrecy. In their view, university–industry collaborations can be viewed as part of a professor's strategy to share findings and expertise with the wider scientific and technical community, whereas industry funding alone is often associated with a university laboratory acting as a subcontractor to a company's R&D project and may produce the associated secretive behaviors. Moreover, they did not find a significant relationship between patenting and secrecy, although their statistical analysis showed that applying for a patent is marginally significant in predicting the secret behavior of mathematicians and physicists, not biologist. The result is different from the findings of Blumenthal et al. (1997) and Campbell (2002). To summarize, we may say that secrecy is a potential by-product of the academic competition and that the influence of industrial collaborations are still difficult to evaluate.

1.3.3 Scientific productivity of academic inventors: substitutes or complementary tasks

Empirical work has shown evidence of a positive relationship between the academic quality of an organization and the likelihood of its involvement in commercial activities (e.g., Ambos, et al., 2008; Gittelman and Kogut, 2003). But what interests us is whether patenting abets or hinders a scientist's publication activity. As we have already highlighted the increasing availability of patents and papers data on the electronic form has plummeted the cost of extracting such data, leading to a buoyant number of papers investigating the productivity of academic inventors.

Looking at sheer numbers, patent and publication counts, many studies tend to show a rather positive effect of patenting on publications. Based on a matched sample of patenting and non-patenting US scientists, Fabrizio and DiMin's (2008) results suggest that publication and patenting are complementary activities, not substitutes, for faculty members. Focusing on a sample of US academic life scientists, Azoulay et al. (2006) find that patenting increases the number of publications. Similar results can be found in Calderini and Franzoni (2004) for Italian researchers in materials science. Breschi et al. (2006) and Carayol and Matt (2006) find a similar link, respectively for a larger sample of Italian researchers, and for University

Louis Pasteur in France. These results are however at odds with Agrawal and Henderson's (2002) who did not find a significant relationship between the number of publications and the past patenting activity of a sample of MIT researchers.

Looking at the opposite causal links, a high scientific performance in terms of publications turns out to increase the probability of filing a patent. For instance, using data of Italian academic inventors Breschi et al. (2005) found that they do not publish less than their non-patenting colleagues and do not show any bias towards more applied, less basic science.[37] Their results even tend to indicate the opposite, namely the existence of a positive link by which more productive professors are more likely to patent. In this respect, similar results have been obtained by Stephan et al. (2007) for the US case, Carayol (2007) for France, and from a large sample of German academic inventors (Czarnitzki, et al., 2007).

All the above-mentioned empirical evidence broadly comes to terms on a positive relationship between patenting and publication outcomes, in both directions, for academic researchers from the US and many European countries.[38] On the company side, interviews with Japanese R&D managers conducted by Hicks (1995) indicated that if things can be patented, they can be published. However, when it is not possible to patent research secrecy is preferred, making publication difficult if not impossible. We can postulate the same tendency in the academic community as evidence in the life science sector supports this idea.[39]

A related concern is that the quality of research might suffer from increased commercialization activities of scientists. However, most empirical evidence supports a positive relationship between patenting and publication quality.[40] As a result, one can argue that the two activities go together well and smoothly, but as often the devil is in the details. Czarnitzki et al. (2009) went a step further in trying to disentangle this relationship. In their study on German academics in-

[37]A shift towards more applied research of the research agenda is often referred to as the 'skewing' problem (Florida and Cohen, 1999).

[38]Evidences on Asia are lacking, Chapter 2 will venture in filling up this void.

[39]In the life science community a growing number of ideas once placed solely in the public domain are now additionally patented, scientists disclose their results in both publications and patents (Murray and Stern, 2008). We will address this idea in more detail in Chapter 4.

[40]Publication quality is evaluated by the number of citations an article receives, the higher the better, and/or by the quality of the journal it is published in.

volved in patenting activity, they made a distinction between patents assigned to corporations and patents assigned to non-profit organizations such as universities, private patents (owned by the scientist herself) and public (research) institutions. Their insight was that the contents of these patents might be different. This intuition is also found in the work Trajtenberg et al. (1997) as they have shown that corporate patents differ from university patents in that they are more applied in terms of technology content, or possibly contain more incremental elements. They reveal the following results: patents assigned to non-profit organizations (including individual ownership of the professors themselves) complement publication quantity and quality. Patents assigned to corporations are negatively related to quantity and quality of publication output.[41] On a similar line of inquiry, Thursby and Thursby (2009) created a sample of US university-invented patents,[42] a patent with at least one university inventor but with an ownership that could belong to a university or a firm. They conclude that patents assigned to firms are less basic than those assigned to universities. A recent work by Wang and Guan (2010), centered on Chinese academics in nanotechnologies, reports a decline in both quantity and quality of publications generated by a researcher following the application year of a patent when the assignee list includes a corporation. Put it simply, patent ownership seems to matter and certainly deserves more attention.

In the same line of analysis we can state the results of Fabrizio and Di Minin (2008). Using a panel data analysis on US faculty members, they found that patenting and publication outputs are rather complementary, however faculty members that patent repeatedly their research results generate publications that receive fewer citations. This could point to a lesser interest towards their research by the academic world. This may also indicate a trend towards refocusing their research on more applied or commercially-oriented research, at the expense of fundamental science. Azoulay et al. (2006) found that actively patenting academics may be shifting their research in ways that make their output more relevant to questions

[41] Results on corporate patents are less robust, only at the 10% level of signicativity.

[42] Even though employment contracts in US universities specify that inventions resulting from faculty research belong to the university when university resources are used in the research, they found that only 62.4% of the patents of their samples were assigned solely to universities.

of commercial interest. In an event history model on Italian scientists in materials research, Calderini et al. (2007) assess how a researcher's individual characteristics (mainly the kinds of publications they do) affects his ability to patent. They found that scientists working on applied research are significantly more likely to become academic inventors than their colleagues that work on "very basic/fundamental" understandings. More interestingly they found that while the former are more likely to patent if they increase the amount of research they do, this is not true for the latter group of individuals.

In our view, the evidence provided by the empirical literature supports the idea that patenting and publishing complement each other. Academic scientists do not seem to suffer from patenting but considerations of ownership of the inventions and intensity of patenting appear to influence the researchers' agenda. Additional questions remain open as to the exact effect of academic patenting at the systemic level. We discuss this point in the next section.

1.3.4 The anti-common hypothesis

Since patents are rights to exclude, and as we have shown that scientific research may be viewed as a cumulative process, the boom in academic patenting has raised serious concerns about the future freedom of researchers. Heller and Eisenberg (1998) popularized the expression "tragedy of the anticommons" in an article published in *Science*. Their argument is that the increased use of patenting in the field of biomedical research may actually stall innovation. Indeed, privatizing the scientific commons may inhibit the free flow and diffusion of scientific knowledge and the ability of researchers to build cumulatively on each other's discoveries. A famous illustration of this effect is the grant accorded to Harvard university by the USPTO[43] of the infamous oncomouse patent (a transgenic mouse designed to have a predisposition to cancer). As DuPont funded the research related to the discovery, it received an exclusive license. Subsequently, DuPont enforced its exclusive right with hubristic force for a decade, undermining the collective creation of knowledge and sharing of research tools and results among scientists (Murray,

[43] United States Patent and Trademark Office (USPTO).

2009).

Murray and Stern (2007; 2008) designed an creative experiment to test the anti-commons hypothesis. They utilized the fact that often the same idea is penned in papers and patents, thus forming what they called patent-paper pairs. They document the fact that such patent-paper pairs are widespread in the life sciences community, where knowledge is often simultaneously of scientific and commercial interest. To estimate the influence of patenting on subsequent research, they take advantage of the fact that patents are granted with a substantial lag, often many years after the knowledge is initially disclosed through publication. The knowledge associated with a patent-paper pair therefore diffuses within two distinct intellectual property environments, one associated with the pre-grant period and another after formal IP rights are granted. Using difference-in-differences methods, they report findings demonstrating that although publications linked to patents are associated with a higher overall *citation* rate,[44] the rate declines substantially (by 9-17%) after the issuance of the patent. The authors note that the decline is particularly salient for articles authored by researchers with public-sector affiliations, such as university professors. The question is further addressed by Rosell and Agrawal (2009) who explore the university patent premium - the fact that university patents are believed to be more important, general, and original than firm patents. Whereas Murray and Stern focus in the decline of knowledge flow, Rosell and Agrawal investigate the possible "narrowing of knowledge flows to a relatively more concentrated set of recipients". Indeed, in order to mitigate potential conflicts regarding the patents and licenses and to maximize future profits from the patents, it makes sense for a researcher to narrow the scope of citation to prior art holders. Accordingly, they found that knowledge inflow, the diversity of citations to prior art, has narrowed, this phenomenon being mainly limited to the field of electronics. Conversely, knowledge outflow, in terms of the breadth

[44] Citations to previous literature are often used to evaluate the quality of a patent. In the process of filing a patent, the patent officer is aided in compiling a list of prior knowledge, used in creating the invention, by the patent applicant who is legally bound to provide with the application a list of all patents and publications that constitute relevant "prior art". Citations of prior patents thus serve as an indicator of the technological lineage of new patents, and bibliographic citations indicate the intellectual lineage to academic research.

of patent citations, has declined from the beginning of the 80s to the 90s, though the narrowing was limited to a few fields, namely biotechnologies and pharmaceuticals. Their results illustrate the possible restriction overtime of a widespread flow of knowledge associated with university inventions. They argue that this phenomenon illustrates the changing objectives of university intellectual property from broad knowledge dissemination towards limiting access, as they phrase it:

> This finding may reflect a change over time in the manner by which university researchers conduct research. Rather than merely worrying about patentability after an invention has been created, researchers may increasingly plan research projects with an eye towards commercialization (Rosel and Agrawal, 2009, p. 3)

1.3.5 Business as usual

We have seen that a potential anti-commons effect was perceptible. A related question is whether academic patents are becoming more similar to corporate patents. Henderson et al. (1998) investigate the possible change in the quality of university patents that accompanied the significant growth in university patenting during the period 1965-1988. Their aim was to test whether the increase of the number of academic patents had the unintended effect of producing less "important" and "general" patents, as opposed to the believe that university patents would be more highly cited (important) and cited by more diverse patents (general) than a random sample of patent. Based on the analysis of patent data from 1965 to 1988, their results suggest the following trend: university patents used to have more forward citations[45] and were more general than a random sample of all patents in the pre-Bayh-Dole period. However this difference has declined overtime. The increase in the number of academic patents is much evidenced, whereas the level of commercially important inventions has not followed. On the other hand, the methodology has been criticized by Sampat et al. (2003), who have made the same analysis using a larger timeframe in order to avoid a truncation bias due to a lack of observations (after 1992). Their analysis suggests that during the post-Bayh–Dole period, the lag between application and issue dates for

[45] Number of citations received by each patent following its issue.

university patents has increased, and that citations[46] to university patents occur somewhat later, on average, after issue, but they did not find a significant change in the total number of citations. However, if later citations, as argued by Lanjouw and Schankerman (1999), are a sign of less economic importance, it can still go in the direction of Henderson et al., as latter citation relates to a smaller impact. However, a more decisive argument concerns the increased delay before citation. If you assume citation as a trace of assimilation of the knowledge embedded in a patent, and if you acknowledge the need for "knowledge complements" in acquiring the information in patent, you might need personal contacts to assimilate the tacit components of a patent. This would suggest that university research is disseminated more slowly as a result of a higher emphasis on proprietary aspects compared to the open science norms.

Another explanation, yet not contradictory to the previous statement, can be found in Mowery and Ziedonis (2002) who showed that inexperienced academic patentees appear to have obtained patents that proved to be less significant than those issued to more experienced university patentees. The rise of the pool of academic patentees seems to have decreased the overall quality of academic patents. Patenting might be seen as a "business as usual" operation, maybe to the detriment of originality and breadth of the protected discoveries. Food for thought might come from results of a survey on more than 500 higher education institutions in the US by Coupe (2003). He showed that 372 of the institutions were not listed on any patent at all: will they embark in the patenting buzz, and if so what are the potential consequences?

1.4 Research paths for an empirical analysis

In general, the empirical literature supports a positive relationship between patenting and publishing. There are, however, important differences among fields, universities and types of academic entrepreneurs, underscoring the need for a nuanced vision when investigating the effects of patenting and more generally com-

[46]Citations are a noisy measure as they are not by the inventor but are added by patent examiner. See Rosel and Agrawal (2009) for a review on the subject.

mercialization activities on the ethos of academic science. We first investigate how a more subtle picture could be portrayed, and then formulate concluding remarks. In this section, we introduce some of the elements we will develop in the following chapters: namely the need to adopt a circumstantial approach when talking about the influence of industrial science practices on academic science and the need to understand the motivations and adaptation mechanisms of academics who engage in technology transfer activities.

1.4.1 Call for a differentiated approach

As many studies have shown that prolific academic writers are also serial patentees, it may be useful to try and gain a better understanding, first of how differences in researcher profiles influence one's propensity to engage in commercialization activities (a), and second to acknowledge potential systemic differences regarding the field of research (b).

a. Scientist level

Table 1.1: Pasteur's Quadrant

	Consideration for Use?		
Quest for fundamental understanding?		No	Yes
	No		Pure Applied Research (Edison)
	Yes	Pure Basic Research (Bohr)	Use-Inspired/ translational Basic research (Pasteur)

Source : Stoke (1997).

In our view, the first level of analysis to take into account in approaching the different ways an academic researcher interacts with the industry lies in the type of research he or she is conducting. Although this formulation is in itself tautological, we believe in its force. The different methods and goals pursued by researchers are a characterizing factor behind differences in the ease of university-industry interactions. To be clear, we are not talking here about the basic vs. applied dichotomy of research activity but about the objectives pursued by a given scientist. Rather we propose to use Stokes' (1997) classification of research activities called "The Pasteur's Quadrant". Stoke offers us to move from the basic vs. applied classification to a two-dimensional plane, with research being categorized according to two axes of inquiry: the vertical axis represents the degree to which he seeks to extend the frontier of fundamental understanding, and the horizontal axis the degree to which the research is guided by consideration of use. To help fix the meaning of these two dimensions, Stokes proposes a quadrant[47] model of scientific research (Table 1.1). Because we are looking at the goal of research - whether the researcher is seeking to discover fundamental truth or to apply of his research - we are focused on the intended output without being trapped in the process of achieving this goal.

The first (North-East/upper right) quadrant contains scientists who are looking to solve problems and have in mind an application of their research, whether far away or in proximity. Their work is guided solely by applied goals without seeking a more general understanding of scientific phenomena (Edison scientists). The second quadrant (South-West/lower left) consists of scientists who seek an understanding of fundamental knowledge. They have little interest in the use of their research. They represent the vision that many have of a university professor in his ivory tower evolving in the Humboldtian tradition (Bohr scientists). Last, but not the least, quadrant (South-East/lower right) encompasses Pasteur type scientists. They manage to combine both dimensions, a quest for fundamental understanding allied with an interest towards practical applications.

We can hypothesize that each kind of researcher will have different ways to interact with the industry and to combine proprietary and open knowledge. An intuition of this claim can be gained from research practices of Louis Pasteur himself. In particular, things can be learned from the way Louis Pasteur used different methods to diffuse one of his major inventions, the anthrax vaccine. In 1889, a Canadian biologist requested to stay in Pasteur's laboratory in order to learn the methods to produce the anthrax vaccine he had invented. Pasteur differentiated his responses

[47] A quadrant represents each of four parts of a plane divided by two lines at right angles.

between contexts in which the knowledge would be acquired, whether academically or commercially. In the first case, he could receive academic training in the Pasteur Institute. In the second situation, in order to learn the know-how of producing the vaccine, the knowledge transfer would be subject to an agreement from the holder of the commercialization rights, a laboratory created by Pasteur himself for this purpose (Cassier, 2005). This example reveals how Pasteur was able to pursue two streams of research, and make a difference in the way he diffused their output. The first stream, the theoretical inquiry on the principle of microbe attenuation, was based on the norms of open science with freely available results. The second one, the expertise on the production of vaccines, was governed by the commercial system that he had helped set up. In that case, the access to the laboratory expertise to produce the vaccine was restricted and subjected to license contracts. There were two reasons for that. First, he wanted to control the quality of the vaccine produced as the method of production was not yet perfectly stabilized, and second, he could derive revenue from vaccine sales to enable a financial independence for his laboratory. Pasteur-type scientists are interesting because they are more inclined to the dual demands of academia and industry.

On a related level it has been argued that in Pasteur's Quadrant, including sciences such as biotechnology or informatics, codification of new knowledge can be achieved through publications or patents, at relatively lower costs for translation from one to the other when compared to other scientific fields, and that both types of outputs are accepted by their respective epistemic communities. We address this level of analysis in the next section.

b. Scientific level

Scattered empirical evidence can be found in the literature about the differences among technological fields regarding researcher's commercialization behaviors and attitudes towards commercialization activities. As a matter of fact, some of the most investigated fields are those related to bio-science and bio-technology, the reason being that since its creation, the biotechnology industry has been closely linked to university-based science (Gambardella, 1995; Kaplan and Murray, Forthcoming; Kenney, 1986). Emblematic of this close cooperation is the work of Herbert W. Boyer and Stanley N. Cohen who were the first in 1973 to demonstrate recombinant DNA (rDNA) techniques (Cohen, et al., 1973). This discovery is seen by many observers to mark the start of biotechnology in the marketplace. Nearly one year later, convinced by Niels Reimers, founder of Stanford University's technology commercialization program in 1970, they filed for patents claiming that both the process of making rDNA and any products that resulted from using that product should be attributed to them. As a result three patents were granted. Over the duration of the life of the patents (they expired in December 1997) the technology was licensed to 468 companies and generated $255 million in licensing revenues (to the end of 2001) for Stanford and the University of California (Feldman, et al., 2007). In that respect, substantial evidence shows that the surge of academic patenting has been developed in parallel with the development of life science and more specifically biotechnologies by universities (Mowery, et al., 2001; Sapsalis, et al., 2006). Evidence in Europe shows that academic patenting represents a large share of all the patents in the biotechnology area with up to 15% of all applications as opposed to, for instance the automotive industry where the share is around 1% (Zeebroeck, et al., 2008). The question is then, how is the technological field shaping scientists' response to commercial opportunities? Using interviews with entrepreneurial professors, Gulbrandsen (2005) tells us that health science entrepreneurs generally describe situations where academic and entrepreneurial work may be effortlessly integrated. Physicists are, on the other hand, often skeptical regarding the increase in patenting because it limits further research and innovation. Analyzing surveys from three academic fields, Hong and Walsh (2009) found that the secrecy issue is particularly strong in experimental biology. Looking at invention disclosures in six American universities, Thursby and Thursby (2003) found that biological and engineering sciences were more likely to apply for invention disclosure. Investigating the university patent premium, Rosell and Agrawal (2009) found that it was narrowing, especially in the field of biotechnology and pharmacy. A similar picture of heterogeneous patterns of collaboration varying from field to field emerges as well with a broader vision on UI collaboration. In chemistry, provision of skilled students and informal contacts play a specifically important role in co-operating with the industry (Meyer-Krahmer and Schmoch 1998). In engineering disciplines, commissioned and collaborative research, labor mobility, and influx of students are found to be important (Meyer-Krahmer and Schmoch 1998; Balconi and Laboranti, 2006). In the pharmaceutical industry, where patent is believed to be an efficient means of protecting invention (Levin, et al., 1987), academic patenting is a common channel of cooperation. These various empirical findings lead us to believe that depending on the discipline, various mechanisms and practices are used to transfer university technologies.

It can be argued that differences originate in how each discipline appropriates the norms, goals and practices of conducting research. Owen-Smith and Powell (2001) showed in their comparison of life sciences and physical sciences faculties, that cultural norms across scientific fields are critical in shaping faculty involvement in entrepreneurial activities. For instance, regarding academic patenting they note that:

> [P]hysical scientists believe patents provide leverage at multiple levels, within the university, in relationships with firms, and in federal grant competitions. Life scientists are more concerned with patents as a means to attract investments in their research from firms and venture capitalists. The life-scientists' image is less one of building a relationship than of capital infusion.

While life scientists focus on the proprietary benefits of patent, physical and engineering scientists tend to emphasize the relational benefit of patents as a facilitator to industrial collaboration. Elements pointing towards this thesis can also be found in Klitkou and Gulbrandsen (2010). In a study on academic inventors in Norway, they report that in the physical sciences, academic inventors co-authored their scientific papers more frequently with industry, as compared to the control group of non-inventing peers. They did not find such a correlation in the life sciences.

We can find some theoretical justification of these differences in the work of Asheim and Coenen (2005). They argue that the innovation process is particularly dependent on their specific knowledge base. They define two types of knowledge: analytical and synthetic. Analytical knowledge builds on formal scientific basis where knowledge creation is often based on cognitive and rational processes, or on formal models. These types of mechanisms are common in genetics, biotechnology and general information technology. The inputs and outputs of this type of knowledge are often codified. Synthetic knowledge takes place mainly through the application of existing knowledge or through new combinations of knowledge. It is generated in response to the need to solve specific problems, where interaction between the involved actors is needed. In this setting tacit knowledge is important and cooperation is essential to solve problems. This type of mechanism is common in the field of engineering. In that way we can hypothesize a more collaborative type of approach of UIR in the engineering and physical sciences, and a more codified and legal basis in the life-sciences sector.

In Chapter 4 we investigate further this line of analysis. Drawing on in-depth qualitative interviews with Tohoku University faculty members, we use Stokes' classification to identify potential differences among researchers in the field of materials science and engineering regarding the combination of technology transfer activities and more traditional academic objectives. This leads us to put forward the concept of "hybridization" of research practices in the academic world as the response to new stimuli. This element is developed in Chapter 5.

1.4.2 Why engage in academic patenting?

Very little is known about the involvement of individual university researchers in the knowledge transfer process. Only a limited number of studies analyze UIR from the point of view of an individual university researcher. Skimming the literature we were surprised to find that relatively little is known about the actual motivations and perceptions of the researchers to engage into commercialization activities, or how they perceive the influence of UIR and IPRs on their research. In our view there is a need to have a "grounded", "micro" approach of UIR. Theory is still in its infancy for understanding the motivations to cooperate. This observation led us to design a survey, which was sent to academic inventors, to investigate the motivations and consequences of technology transfer activities. By looking at the motivations of researchers and by exploring their views on these questions, it may be possible to open the "black box" of academic science. Results are presented in Chapter 3.

Let us have a quick look at the available findings in litterature. In a frequently quoted study based on qualitative data, Owen-Smith and Powell (2001) investigated the reasons behind the differential rates of commercial success on the two campuses and examined how faculty's perception of patenting affect such outcomes. Based on an analysis of 68 interviews, they argue that faculty disclosure of inventions is shaped by the perceptions of the benefits of patent protection. Distinguishing a distinction between physical and life sciences (see previous section), they summarize beliefs about patent outcomes highlighted by physical and life scientists' accounts about what motivates their decisions (Table 1.2). Table 1.2 is divided into five categories: protection, leverage, money, intangible, and education. What do we learn from these responses? First, in terms of protection, patents seem to play a double role: in one way they are viewed as an enabler of commercialization of university inventions, but more interestingly they are envisioned as a mean to protect academic freedom from commercially held patents. Protecting academic freedom with a fence, isn't it a paradox? Hall and Ziedonis (1996) considered a somewhat similar puzzle in the semiconductor sector, based on survey evidence they noticed that semiconductor firms do not rely heavily on patents to appropriate returns to R&D, yet they patent intensively. One of their explanations is that patents are a kind of "bargaining chip": the more patents you hold in a given field, the greater is your position in negotiating with other players of the field who also have patents. In that sense, patents are not valued for conferring the legal right to exclude others from using a technology, but to obtain more favorable terms in negotiation, safeguarding against patent legislation and hence not being blocked in his/her research. Second, in term of leverage, patents may help to signal competencies for state agencies that want to sponsor applied research. Moreover, they are a way to extract funds from corporate partners as they signal the ability of a researcher to engage in commercially inclined research. But one should remain cautious in interpreting these results, as they reflect the perceived vision of scientists, which may not be an exact picture of the processes at stake.

Financial value is one of the elements cited, but evidence shows that the returns from licenses are very skewed and relatively unprofitable.[48]

UIR studies based on interviews and surveys are increasingly available. We can cite among others the work of Pablo D'Este and colleagues who, in a series of papers based on various large surveys of UK academics affiliated to the UK Engineering and Physical Sciences Research Council (EPSRC) have investigated the factors that influence academic researchers' engagement with industry (Bruneel, et al., 2010; D'Este and Patel, 2007; Tartari, et al., 2010). Welsh et al. (2008), using interviews with 84 biological scientists at nine universities, studied how scientists view UIR and university IP policies. Agrawal and Henderson (2002) examined patenting and publishing behavior of researchers at MIT. Pénin (2010) studied the motivation of academic patentees at Louis Pasteur University in France, and Walsh et al. (2009) reported on the perception that Japanese academics have on the increased commercialization activities of Japanese universities.

We will have a more in-depth analysis of this literature in Chapter 3. The main point here is to emphasize the need to improve our understanding about *who* in academia interacts with industry and *why*? In Chapter 3, we address this issue by analyzing the results of a survey sent to all Tohoku University academic inventors, in order to know *who* in fact is patenting. In Chapter 4, we conduct in-depth interviews with a selected number of researchers in the materials sciences to further advance our knowledge of *how* and *why* these researchers chose to interact with the industry.

[48] Thursby and Thursby (2008) give some numbers on this matter. In the US, in 2004, among 144 universities that have replied to an AUTM survey, the average income per responding office was $7.2 million, $47,722 per active license. Swamidass and Vulasa (2009) have calculated that license income as a percent of research expenditure of the same universities was of 1.7% in 1995 to 2.9% in 2004. Taking into account for wages, administrative fees and payments to other institutions, the net revenue of the license was a mere $1.3 million. In addition, the distribution of revenues is highly skewed. In order to get rich, you have to be among the happy few as there were only 109 (1.24%) of licenses that generated an income yielding $1 million or more in revenues – scientists may be overoptimistic.

1.5 Conclusion

> Economists, it must be said, are for the most part quite happy to study the efficiency of resource allocation in producing and distributing goods and services without stopping to inquire even superficially into the specific natures and concrete shapes of those commodities [...] Considered from that angle, it is perhaps not surprising that the "new economics of science" found it most natural to start by reworking the area of organizational analysis originally ploughed by Mertonian sociology of science, looking at the implications of certain institutional arrangements for allocative efficiency in the production of generic information that acquires a certain measure of reliability but not troubling itself over the nature of reliability in this context, the details of the way that attribute of information might be acquired, or any of the other issues of socio-cognitive interaction that have occupied the sociology of scientific knowledge. (David, 1998b, p.120)

In our analysis, we have depicted the special nature of knowledge, which makes it a good with special properties and calls for special organizational arrangements for its production. Following David's argument, we stress how academic science, embedded in the open science arrangement and Mertonian norms, is able to deliver, in a relatively fast pace, reliable knowledge that can be utilized in a cumulative way. At the center of this system are the mores of the scientific activity that put a great emphasis upon originality and priority, two elements that are central in the retribution of scientists. In that system proprietary rights are contained to the minimum, peer esteem, and non-monetary rewards at the center of the scientific economy. We then highlight the differences that exist between university and industry scientists regarding these norms, and how these differences are somehow blurred, industrialists being more open and academics more fenced-off. For example, we illustrate how academic scientists increasingly pursue research characterized by direct applications, while some firms apparently abide by open science approaches. Indeed, there is considerable evidence that scientists in industry publish and scientists in academia patent, and that the "same" piece of knowledge can be disclosed in different ways.

In reviewing the empirical literature, we survey the use of patents and publications in academia to portray the antagonist demands that these two types of outputs levy on faculty members. Concisely, we pinpoint these two activities to complete each other rather well at the individual level but that evidence of problems at the institutional level is present, such as a possible negative effect on the fast accumulation of knowledge - the anti-commons hypothesis - and a decrease in the quality of patents filed by academic organizations.

Finally, we carved out some research paths to explore the lack of depth and diversity that exists amongst many studies addressing the influence of industrial science on academic practices . We called for a more differentiated approach in treating the subjects of UIR, technology transfer and commercialization initiatives from universities, especially regarding the "type" of scientists and their field of expertise. Response by the academic community are not even across the spectrum of scientific disciplines and research motivations, this heterogeneity has to be taken into account when designing an empirical strategy to tackle these questions. As David's quote above expresses, we need to get a better image of the members of the system and how they interact, without paying too much attention to the details of their whereabouts. Our task for the rest of this work will be to take these elements into consideration while conducting in-depth research centered on a Japanese research-intensive university, Tohoku University. This case, in our view, offers many opportunities to analyze the influence of commercialization activities on academic researchers, as it is an institution combining academic excellence with high levels of industrial collaborations and technology transfer activities.

Table 1.2: Faculty perception of academic patenting

Outcome	Physical Science	Life Sciences
Protection	Limits restraints on communication	Protects academic freedom from commercially held patents
	Enables commercialisation	Enables commercialisation required for drug development
	Limits actions of foreign competitors	Keeps findings from being "robbed"
		Keeps faculty from being "skinned" by firms
		Keeps faculty from missing the "golden egg"
Leverage	Enables requests for funds from deans, department chairs	Helps convince firms to pay for development research
	Leads to consulting and sponsored research	
	Aids in obtaining federal grants by getting private equipment	
Money	Getting rich	Getting rich
Intangibles	Curiosity	Serving the public good
	Validation of research	Fighting disease
	Increased prestige	Increased prestige
	Helps forwards "basic science" thinking	Helps advance "basic science" thinking
Education	Helps students get jobs	
	Reading/writing patents, negotiation as professional skills	

Source: Owen-Smith and Powell (2001).

CHAPTER 2

THE INFLUENCE OF ACADEMIC PATENTING ON THE SCIENTIFIC ENTERPRISE: A QUANTITATIVE ANALYSIS

> *Science must not suffer itself to become the handmaiden of theology or economy or state. [...] The persistent repudiation by scientists of the application of utilitarian norms to their work as its chief function the avoidance of this danger, which is particularly marked at the present time.*
>
> — Merton (1938)

2.1 Introduction

Recent work on universities has led many scholars to investigate the consequences and incentives behind academic patenting. This stream of literature began in response to the enactment of the Bayh-Dole Patent and Trademark Amendments Act of 1980, which allowed American universities to receive patents and grant licenses from research funded by the federal government. The number of patents granted to American universities has peaked in 2002 at just under 3,300, compared to 300 in the seventies. The biomedical related patent classes dominate these awards (National Science Board, 2008). Most observers attribute this tendency to the legislative change, but it is worth noting that the trend preceded the Act: Colyvas et al.(2002), based on case studies, argue that two other factors could explain the surge. First, the period saw the rise of important new areas of university research, namely molecular biology and computer science; both of which are of particular interest to the industry. Second, over the same period, various patent offices extended the range of research results that were patentable (Jaffe and Lerner 2004). According to Colyvas et al. these two elements led to the increase in patenting and licensing, the principal effect of the Act being to accelerate these trends.

The increasing reliance on patenting raised many questions in the literature. The enthusiasts spoke with emphasis of the increasing role of universities in economic development. The "Triple Helix" concept (Etzkowitz 2003) sees patenting by universities as an indicator of their new involvement in the commercialization activities, beyond the traditional role of research and teaching. In the same vein, Jensen and Thursby (2004) show that the direct involvement of scholars has proven to be a determinant in the success of technology transfer. Skeptics, by contrast, consider that the increase in patenting and commercialization activities by universities could lead to some caveats. The industry may use its growing relative importance to shape research agendas, inducing a redistribution of resources from basic to applied research. Other possible adverse effects of academic patenting include potential conflicts of interest, secrecy issues, delays in the publication process and increased costs of research (Heller and Eisenberg 1998). A growing "anti-commons" perspective highlights the negative role of Intellectual Property Rights (IPR) over scientific knowledge. Academic inventors may have to use patents to protect and exchange their new knowledge. In that respect, patenting is seen as a defensive mechanism to enable the diffusion of knowledge. As commented in Chapter 1, this new situation may create tensions within the academic community, and may be less efficient in term of fast diffusion and validation of knowledge than the previous one relying on pure "open science" because of the transaction and maintenance costs associated with patenting. A large number of studies has examined the impact of patenting activity on academic research; while the majority of the research has been centered on the US and Europe, very little has been said about Asia.

One of the aims of this chapter is to assess the influence that academic patenting exercises on academic science with three dimensions in mind: the effect on academic productivity measured in terms of publications and their quality; the role of financial factors and peer effects in determining the relation between patenting and publishing; and finally the effect of institutional and legal changes in shaping the decisions of academics. In order to achieve this, we examine closely the Japanese case and provide an analysis of a leading Japanese research university, Tohoku University. To our knowledge there is no study available in English on this topic centered on the recent Japanese context. We intend to investigate the mechanisms at stake, and meticulously whittle down the vast amount of information available to generate valuable knowledge. In order to achieve this goal, we take advantage of the availability of patent and publication databases together with data collected on individual faculty members at Tohoku University.

In terms of empirical strategy, our analysis is deeply rooted in micro-data. The first reason why we use this scale is that we wish to focus on individual and laboratory determinant of academic research production. As Bonaccorsi and Daraio (2007) noticed, almost all variables of interest in science and technology are distributed unevenly with a very skewed distribution. By using national indicators, we might miss important specificities of the variables: a local or even an individual unit of analysis is more prone to depict the asymmetric tendencies observed for the phenomena under study. The second reason why we focus on this scale is that we were able to gather precise information on the Tohoku university case. Using relevant data, we aim to explore the relation between patenting and publishing behaviors as a way to evaluate the effects of commercial activities on academic research. Our core research question is to see whether these two activities are complementary or substitutive. In this respect, we take into consideration two complementary dimensions: the link between individual and collective determinants of faculty research productivity, and the varying influence of diverse types of funding schemes. Nevertheless, we are aware that academic patenting is not the only mechanism, not even the main one, of knowledge exchange between the academics and the industrial world, neither that it symbolizes the full range of university-industry relations, other mechanisms such as consulting, training, contract research, meetings, conferences or the creation of physical facilities are present. However, we weigh this enfeeblement by the strength patent carries: their availability and their epitomization of commercial activities by academia.

This chapter is organized as follows. Section 2.2 lays out a brief description of the Japanese case in terms of institutional reforms and their links to academic patenting, before moving to a description of the Tohoku university case. In Section 2.3, we first state our research questions and hypotheses (2.3.1). Our empirical work is based on two complementary research designs. Sub-Section 2.3.2 presents the results of a pooled cross section analysis of a large sample of faculty members from 2004 to 2007. Sub-Section 2.3.3 is based on a panel dataset focusing on a group of early adopters of IP related activities that have been active patentees before 2004. We then summarize the main results of the empirical work and finish with a general discussion.

2.2 The Japanese context

The first part of this chapter gives a concise account of the Japanese reforms that were implemented in recent years to facilitate the commercialization of university inventions and university-industry relations (UIR). The main point here is to highlight how these reforms, and particularly the Incorporation of national university in 2004, have paved the way for a dramatic increase in academic patenting. In the second part of this chapter, we move to the case of Tohoku university – our unit of analysis – to show how the university has embarked vigorously in this trend, by being at the forefront of academic patenting in Japan. This information has set the foundations for our empirical analysis: we rely on two econometric exercises to study the link between academic patenting (a proxy for industrial collaboration) and publication (the traditional output of university researchers).

2.2.1 Technology transfer in academia: Japan

In this section, we introduce the legislative changes that occurred in Japan concerning the university-industry settings. We particularly focus on their influence on the IPR regime, and stress the importance of contractual research in the Japanese setting as a complementary way to transfer knowledge and technology.

a. University reform and IP management

In order to understand the development of academic patenting activities in Japan, it is necessary to restate some key institutional reforms that have led to the dramatic increase in university-owned patents.[1] We will investigate the modifications that occurred in the university-industry legal framework, as well as the the changes affecting national universities' legal status where the majority of academic research takes place.

University-industry collaboration has evolved recently in order to facilitate interaction between the two institutions. Until 1980, restrictive government regulations caused levels of university-industry collaboration to remain low. In 1983, the Ministry of Education relaxed its regulations, and notably allowed national universities to cooperate with industry. However, it is only after the introduction of the 1995 Science & Technology Basic Law and the Technology License Office (TLO) Law that the real changes began. We can step into the argument by briefly stating the main laws that structure the technology transfer activities within universities. Below are the three main laws shaping the legal framework:

(1) The 1998 Law to Promote the Transfer of University Technologies (the TLO Law) legitimized and facilitated transparent and contractual transfers of university discoveries to industry.

(2) The 1999 Law of Special Measures to Revive Industry was the Japanese equivalent of Bayh-Dole Law.

(3) The 2000 Law to Strengthen Industrial Technology established procedures, enabling university researchers to obtain the permission to consult for, es-

[1] In this chapter, we make an important distinction between *university-owned* and *university-invented* patents. We refer to university-owned when a patent has been submitted by a university as opposed to patents covering inventions by academic scientists, but assigned to the individual scientists, public research organizations and, above all, business companies.

tablish and even manage companies. It also streamlined the procedures for commissioned and joint research with companies.

All these legislative changes have been listed here to illustrate the increasing importance that Japanese authorities have placed on university-industry collaborations and one of its corollaries: patenting. Another important regulation is the change in status of national universities and its influence on patenting patterns. The anchoring points of the university reform is the Toyama Plan (2001) named after the Minister for Education, Culture, Sports, Science and Technology, Atsuko Toyama. This plan proposed three major reforms:

(1) The reorganization and incorporation of national universities

(2) The development of universities that conform to the highest international standards by using third party evaluation

(3) The increase of the proportion of competitive funding

The plan recommended that national universities should be transformed into national university corporations (NUC), an institution legally separate from the government. Following these lines, in April 2004, the Japanese government incorporated the national universities as "independent administrative entities."[2] Since 2004, the universities have gained greater autonomy. For instance, they can now recruit more easily academic and non-academic staff. Moreover, they can maintain the ownership of their invention - which was seldom the case before the Incorporation- and manage directly their relations with outside partners. Consequently, there has been a surge in research contracts, in number and amount, as well as in patents.

Since 2004, national universities have been managing alone their intellectual property. Figure 2.1 shows the influence of these changes of status on invention disclosures and patent applications. Invention disclosures have started to rise before the Incorporation, with a strong increase from 2002 and 2003, preceding the

[2]For a more detailed account of the process that led to the Incorporation one can refer to Harayama and Carraz (2008).

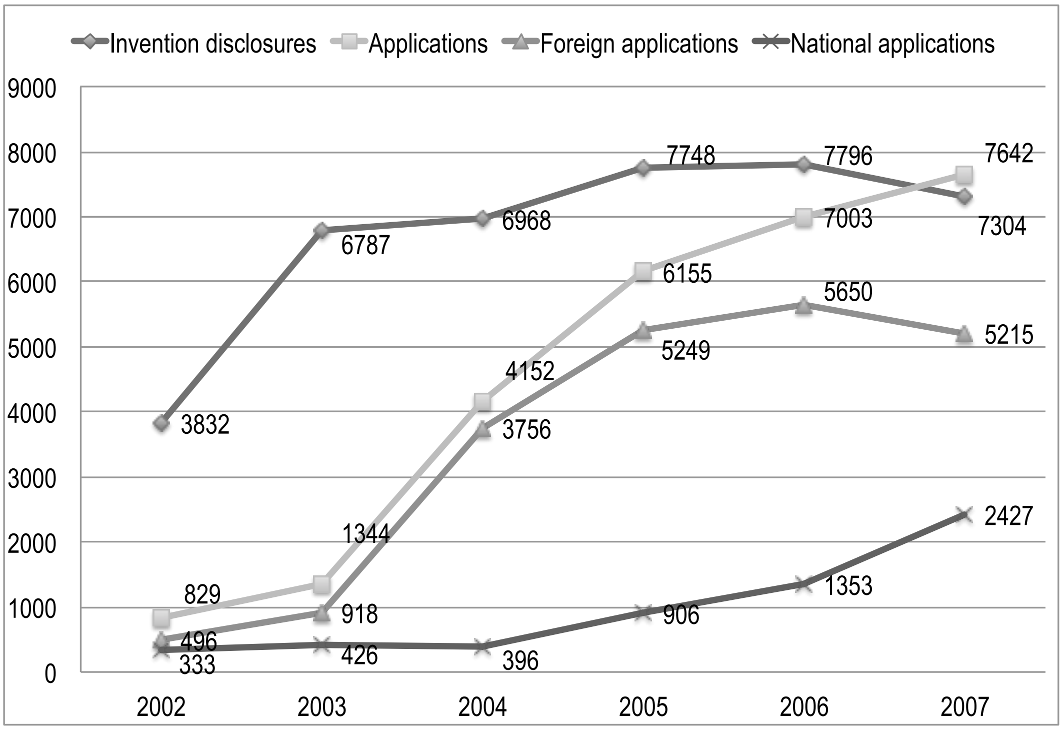

Figure 2.1: Invention disclosures and patent applications by national universities. *Source*: Compiled from various documents on the MEXT website.

increase of patenting. Shortly, thereafter the figures only slightly increase indicating a kind of plateau around 7,500. As for patent applications, the numbers skyrocketed in 2004, and increased steadily thereafter. In 2007, the number of national patent applications decreased for the first time, while the number of foreign applications intensified. These figures indicate two tendencies: first the incorporation entailed a huge increase in IPR activities; second, in 2007-8, the numbers seem to have reached a peak. Furthermore, universities appear to have gained expertise and improvement in the quality of their applications as the number of national applications decreased while foreign ones increased in 2007. Foreign applications are often considered to be more valuable to the applicant as they cost more to start and maintain.

This trend is not specific to Japan. Universities all over the world are increasingly patenting the outcome of their research (Geuna and Nesta 2006; Mowery, et al. 2001). Our data shows that Japan is also following this upward trend. Together with research and teaching, universities are considered the generators of future economic growth. Technology transfer to the private sector has clearly become a desirable outcome of academic research. Nowadays, Japanese universities directly manage their IPR, and thus are more prone to facilitating and advertising the number of patents their faculty can produce. New rules have been enacted concerning the invention disclosure process in order to facilitate patenting.

More precisely, in 1997, the Ministry of International Trade and Industry (MITI), in coordination with the Ministry of Education, Culture, Sports, Science and Technology (MEXT), proposed to extend the support of university-industry cooperation. An important part of this initiative was the creation of TLOs. In 1998, national universities had no independent legal standing. It therefore was difficult for them to apply for patents on inventions by their faculty and to license such inventions. The Technology Transfer Law authorized universities to establish independent or semi-independent TLOs that could sell or license inventions and distribute royalties to inventors and universities. However, academic inventors were not obliged to assign their inventions to the TLOs and could continue to transfer them directly to companies. Kneller (2003) suggests that inventors often turn to the TLOs when an invention has no takers.

In order to establish a comprehensive IP management procedure, from the creation and evaluation of IPR, to their management and licensing, the MEXT established a program to support the creation of in-house IP management offices (hereinafter referred to as "IP offices") within universities. In August 2003, just before the Incorporation, 43 universities had launched an IP office to develop their own technology transfer management system. Their responsibilities partially overlapped those of TLOs. In general, IP offices manage the whole IPR procedure from invention disclosure to patent application. They have final authority over patenting and licensing decisions as the patent owners. Some parts of the procedure, which need professional skills such as marketing, patent surveys and licensing, are however outsourced to TLOs. In some universities, relations between the IP offices and TLOs have been managed smoothly, while have encountered some friction. The problem is that they have different decision-making structures in terms of IP management and different ways to deal with research contracts, particularly in the way they manage license earnings, patent costs and contract specifications. Despite the presence of these institutional feuds that currently rock the university administration, there is no doubt concerning the increasing professionalization of the bureaucracy regarding IP management, which directly influences faculty practices, a point we shall address in Section 2.3 of this chapter.

The administration is clearly gearing up in IP management. But what about the figures, do they lead to an increase of patenting in all the university or is it only happening in some institutions? Figure 2.2 shows the number of patent applications by Japanese universities in terms of patents per year: in 2003, 61 universities had applied for 1 to 9 patents, a number that rose to 115 universities in 2005. The tendency is the same for the highest bracket: in 2003, only one university applied for more than 200 patents, in 2005 there were 7. This illustrates the fact that universities quickly embraced the use of patents, at both ends of the spectrum. However, we should remain cautious about the total increase of patents applied by Japanese universities; universities not previously active in patenting account for a significant part of the growth in overall university patenting. This phenomenon has been similar in the US in the 70s, as noticed by Mowery et al. (2001).

b. Contractual research

The second point we wish to put forth is that patenting is only one side of the picture, the second important element is contractual research, a key aspect in Japanese universities' technology transfer policies. Contractual research is one of the main channels of university-industry collaboration and IP-related activities. In that respect, it has two important characteristics. First, research resulting from such contracts is likely to be licensed smoothly as a result of an existing industrial partnershisp; second, IPRs are at the center of the negation process when finalizing a contract. We attempt to explain concisely how this operates in the following.

If a company, or any organization, wants to have a formal research agreement with a national university, then it generally chooses to enter into either a commissioned or joint research contract with the university. In the case of *joint research*, the

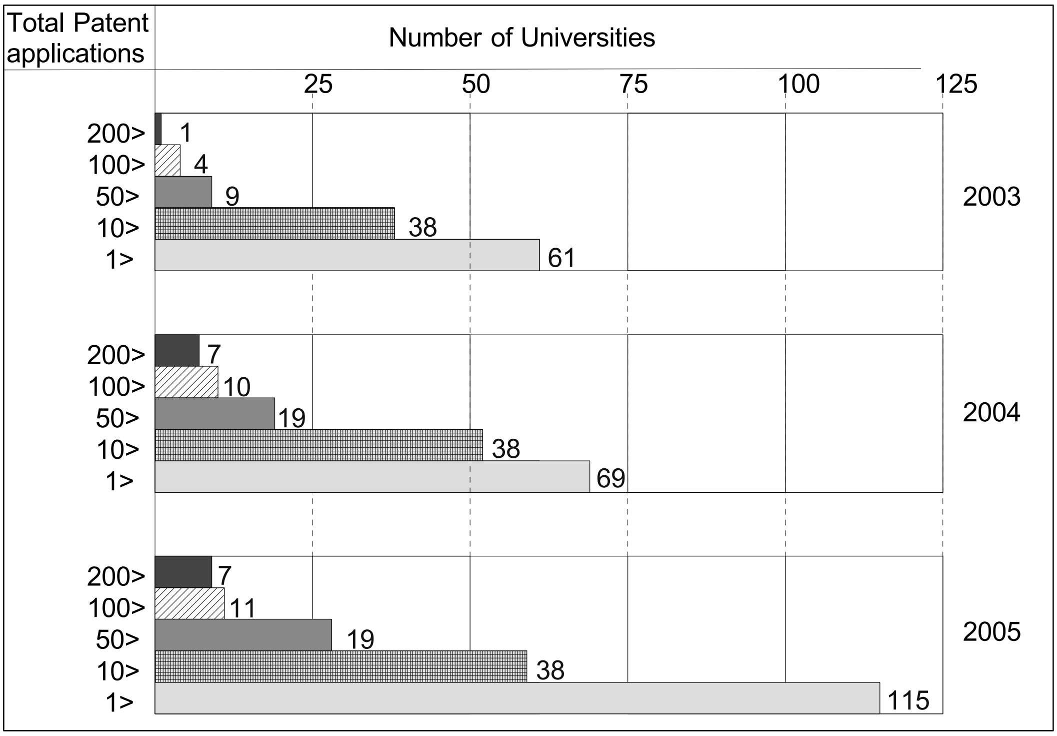

Figure 2.2: Patents applied by Japanese universities according to frequencies. *Source*: UTTA (2007).

university receives funds and research personnels mainly from private firms to conduct research on common projects. Under *commissioned research*, researchers in universities are appointed by firms, research institutes, or governmental agencies to carry out a research project defined by a contract. The main difference between these two types of contracts are that in joint research, company researchers can work in the university laboratories, while this option is not available under commissioned research contracts. More than 80% of commissioned research projects are conducted with the national government or with a private company under a national project scheme. On the contrary, the bulk of joint research contracts are directly carried out with private companies.

Joint and commissioned research is an important means of technology transfer for Japanese universities. The legal framework was enacted in 1983, and such transfers have grown in number and yen value ever since. Table 2.1 shows the trend over a 20-year period. Over the last ten years, joint research has been multi-

Table 2.1: Contractual research by national universities

Category	fiscal Year 1985	fiscal Year 1995	fiscal Year 2005
Joint Research	216	1,704	12,405
Av. Amount per contract	¥5,157,405	¥2,413,730	¥2,442,790
Commisonned research	1,700	3,027	10,082
Av. Amount per contract	¥2,051,765	¥4,662,370	¥10,926,640

Note: The numbers are compiled from the MEXT website; $1= ¥120

plied by 7 and commissioned research by 3. For joint research the average amount spent on one contract has been stable - if we exclude the first years' deacrease - whereas for commissioned research the amount has been increasing steadily.

These contracts are valued highly by companies as a way to initiate collaboration with universities and to do research. To back up our claim, we could cite a MEXT (2007) survey which was sent to Japanese companies with a capital superior to ¥1 billion to better understand their research strategies. One part of the questionnaire was related to their outside partners, especially universities. Japanese universities ranked first when companies were asked where they intended to spend more money for external research. When asked to provide an appreciation of their joint activities with Japanese universities, 36.8% judged contractual research with universities as a positive experience, while 49.9% of the companies cited an ability of universities to solve complex problems. More specifically, a question was formulated to evaluate the pros and cons of conducting contractual research with universities. On the positive side, the three most common answers were: the enhancement of the firm's research capabilities, the outsourcing of basic research, and the creation of a research network. On the negative side, the top three were: the non-applicability of some university research, the lack of secrecy, and the difficulty to gain a monopoly on the IP resulting from common research. This shows that companies value their collaboration with universities, as it expands their knowledge capabilities. They do have some concerns, however, about the openness of the relation, which might be seen as a possible threat to the traditional open environment of university research. We test this dimension in the econometric section. More precisely, we examine the extent to which industrial partners hamper the publication activity of faculty members.

So far, our argument can be summarized in three points: first, the legal environment has been amended to ease university-industry relationships; secondly, university-applied patents and contractual research increased steadily; finally, the Incorporation of national university appears to have played a major role in providing more autonomy for managing IPs.

2.2.2 Academic patenting: Tohoku University

This section presents some important elements concerning the patenting activity of Tohoku university, a leading Japanese research university. The aim of this section is to show how it has adapted itself to a new environment favorable to patents.

a. A short presentation

In this section we briefly present our unit of analysis, Tohoku University, and provide figures on the recent trends in its patenting activity.[3] Tohoku University was founded in Sendai in 1907 as Tohoku Imperial University. It was the third Imperial University in Japan. It is located in Sendai, the most important city of the Tohoku region (North-East of Japan). It is recognized as a strong research university: the 2010 Shanghai academic ranking place it in 5th place among Japanese universities and internationally ranked 20th internationally in the field of engineering and technology, and 39th in natural science.[4] The Thomson ISI list of the most cited papers in the world ranked Tohoku University 3rd in the field of material science, 13th for physics and 22nd for chemistry. In the national context it is widely recognized as one of the flagship universities.[5]

[3] More general information about the university can be found in the Appendix A.

[4] The Academic Ranking of World Universities (ARWU) was first published in June 2003 by the Center for World-Class Universities and the Institute of Higher Education of Shanghai Jiao Tong University, China, updated on an annual basis. We refer to this ranking as the Shanghai academic ranking, its common short denomination. For more information see http://www.arwu.org/.

[5] "Flagship universities" in Japan are defined as top national and private research universities (Yonezawa 2007) – namely, the seven former imperial universities (Hokkaido, Tohoku, Tokyo, Nagoya, Osaka, Kyoto and Kyushu); the Tokyo Institute of Technology (a top national university in engineering); and three leading private universities (Keio, Waseda, and Ritsumeikan).

During the period from 2004 to 2009, 601 faculty members have been listed as inventors on at least one patent applied by the university or the university TLO. This means that approximately 21% of the faculty members have been listed on a patent since Incorporation. As scientists in social sciences and in humanity disciplines seldom do research that lead to patent, the share is bigger if we compare it to the Engineering and Science related faculty members, making the figures jump to nearly 50%. We can compare these figures to similar data available for the Massachusetts Institute of Technology (MIT) where, from 1983 to 1997, approximately half of the teaching staff has been involved in at least one patent (Agrawal and Henderson, 2002). This puts Tohoku University at the same level as an institution widely known for its entrepreneurial and technology transfer activities, and makes it an interesting experimental setting to evaluate the influence of academic patenting on faculty members' research productivity in Japan.

b. University-owned and invented patents

In order to measure the Tohoku University patenting activity, it is necessary to make a distinction between university-owned patents and university-invented patents. University-owned patents are patents for which the ownership belongs to the university. Unfortunately, data on university-owned patents only offer a relatively comprehensive picture of faculty patenting activity in the US and Canadian cases. In the European setting, at least for the 80s and 90s, this information is less reliable as a majority of the patents invented by academic personal were not applied by the university. Looking at university-owned patents gives a wrong picture of the patenting output of faculty members, it creates a downward bias. This is due to the tendency of European academic researchers to leave the property rights of their invention to the firm that financed the project, while still being included in the list of inventors. To account for this problem, it is necessary to introduce the concept of university-invented patents, which cover inventions by academic scientists, but assigned to the individual scientists, public research organizations and, above all, business companies. Lissoni et al. (2007) suggest that university-owned patents in France, Italy and Sweden represent no more than 11%

of all university-invented patents (69% in the US), while business-owned patents represent 60%-80% of the applications (25% in the US).

In the case of Japan, until the Incorporation, university-invented patents were believed to be the norm as the majority of the IPs were transmitted to the companies by-passing the university administration. Kneller (2003) illustrates how a majority of university discoveries were transferred directly from inventors to companies under the disguise of donations, the researcher being listed on the patent application as an inventor. The Incorporation of national universities in 2004 meant that universities would own and enforce all the inventions made by their employees. This mainly explained the strong upward trend of academic patenting for the years 2003-4 in Figure 2.1.

In the Japanese context, Walsh and Nagaoka (2009) found that Japanese universities, much like European universities, used to own a minor share of their scientists' patents. According to their estimations, before 2004 they reckon that around 83% of university researchers' inventions in Japan were not assigned to the university. Recent reports from the National Institute of Science and Technology Policy (NISTEP) investigate the changes entailed by the policy reforms. Shibayama and Saka (2010), using results from MEXT survey, report that, as of 2007, more than 90% of public universities had formal policies to attribute the invention rights of faculty members to the universities.[6] Kanama and Okuwada (2007; 2008) analyze directly this phenomenon and clearly show the visible trend before and after the Incorporation for three universities: Tsukuba, Hiroshima and Tohoku. We present here their main results for Tohoku University. Nonetheless, it can be noticed that these tendencies are similar for the other two universities.

The researchers (Kanama and Okuwada, 2007, 2008) compare university-invented and university-owned patents for the period 1993-2007. University-invented patents are often difficult to unearth. Therefore, to achieve their goal, the authors used the following strategy. In order to gather information on inventors, they retrieved from Tohoku University administration the names of all faculty members who re-

[6]The top 100, out of 87 national and 86 public universities, represent the 100 universities that obtained the largest amount of Grant-in-Aid for Scientific Research (i.e. national research grants) in 2007.

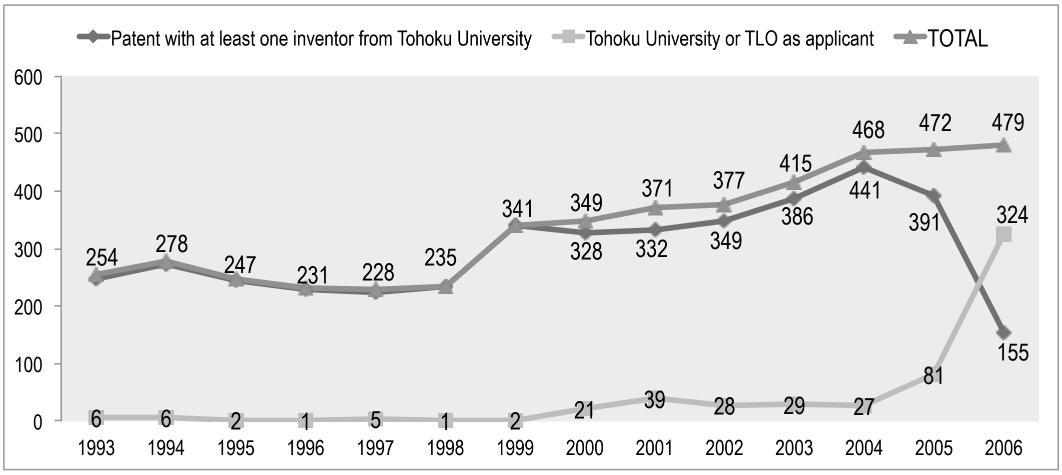

Figure 2.3: Tohoku University patents.
Note: Adapted from Kanama and Okudawa (2008).

ported at least one invention disclosure during the period 1993-2004. Using that list, they searched for all these researchers in the inventor section of the Japanese Patent database.[7] The results of this search are presented in Figure 2.3. The figure describes Tohoku University-owned and invented patents. We see that, up to 1999, university-owned patents were quite inconsequential: the number of patents started to rise in 2000, probably as a consequence of the TLO Law and Japanese Bayh-Dole Act. The figures really show a dramatic increase only after Incorporation. Until 2000, only a minority of the invention disclosures led to a patent application by the university. Alternatively, university-invented patents were quite high throughout the period, with an increase in 1999-2000 and a decrease after 2004 when the university started to manage its IPR more aggressively. Overall, we see from Figure 2.3 that university members have been active in the IPR business on a long term basis, yet there is a constant increase throughout the period with important changes regarding the evolution of ownership through time, from outside partners (mainly companies) to the university. This result enables us to better interpret Figure 2.1. The rise of patenting activity in 2004 did not emerge from thin-air: the potential was not laid dormant until 2004, it just took more informal channels to diffuse it.

[7] A more detailed account of their approach is given in Section 2.3.3, as we used part of their data for conducting a panel data analysis.

In conclusion, the results can be summarized in the following way: as a consequence of policy reforms, the number of Tohoku University patents has risen gradually since 1998. In addition, since 2003-4, the number of patents owned by the university have increased, as more and more of them are replaced by patents filed by tierce institutions, mainly companies. In the next section, we focus on the role of joint research as it plays an important role in the transfer of technology within Japanese universities, as well as Tohoku University.

c. Link between patenting and contractual research

The aim of this section is to portray the close link between contractual research and patenting in the case of Tohoku University, as the old routine of contractual research is being supplement by a new routine, patenting. To begin with, it is important to restate that one of the principal elements of university-industry cooperation in Japan is contractual research. Its importance has been increasing since 1995 (1^{tst} Basic Plan on Science and Technology). This trend preceded and sustained itself after the Incorporation of 2004. As the NISTEP studies have revealed, in the case of Tohoku University, before incorporation a vast majority of the patents were filed with an outside partner (Kanama and Okuwada 2007;2008). Additionally, we have conducted interviews with researchers active in IP activities (see Chapter 4). They explain that it was all too common to transfer the IP rights to the companies they were collaborating with before 2004. This emphasis on transferring the IP rights to the industrial partners has persisted throughout the change of status of universities. Indeed, a large part of academic patents are nowadays co-applied with an outside partner. In 2005, national universities, TLOs and public research organizations have applied for 5,878 national patents, among which 28% were linked to joint research and 15% to commissioned research. Collective research contracts are at the origin of 47% of co-applications (Ijichi and Nagaoka 2007).

This high proportion of co-application can be partly explained by a certain reluctance to changes of the system, as it was natural before the legislative changes for many faculty members to directly transfer IP rights to the companies they were working with. As argued by Kneller (2007), co-application is favorable for the partner of university patents. Article 73 of the Japan's patent law requires the consent of all co-owners of an invention before it can be transferred to a third party, even by nonexclusive license. As such, a company that is the co-owner of a university invention can block the transfer of the university's right to any other company. In exchange the company pays most of the patent application and maintenance costs, but can *de facto* control the invention as in the pre-2004 system, when it was the sole owner.

Table 2.2: Patenting and contractual research at Tohoku University

	2004	2005	2006	2007
University-owned patents	306	414	405	389
Patents links to contractual	No Data	65	98	125
research agreements		(15.7%)	(24.2%)	(32.2%)
Patents solely owned	153	141	129	106
by the university	(50.0%)	(34.1%)	(31.9%)	(27.2%)
Number of contracts (A)	893	1,223	1,488	750
Joint and Commission research				
Faculty members involved (B)	453	547	600	387
(A)/(B)	17.60%	20.10%	22.60%	14.40%

Source: Internal documents

In the case of Tohoku University, Table 2.2 shows that a large proportion of faculty members were involved in contractual research during the period 2004-7. In term of revenues, for the year 2008, contractual research and donations represented 13.6% of the university's incomes.[8] As for patents, 50% were solely owned by the university in 2004. The numbers have been decreasing since. At the same time, the number of patents originating from a research contract is on the rise. In order to gain a better understanding of these trends, we have discussed about the subject with a manager of the university's IP office. He told us that he considered co-applications with industrial partners under favorable auspices as it enabled the university to maintain good relations with companies and it transferred some of the cost of the patenting to them.

Practically, in the case of contractual research, the university manages the IPR in the following way:

[8]Source: Internal documents.

(1) Tohoku University (TU) shall own all IPR arising from the results of its contractual research.

(2) TU may license such IPR to the company for a fee or may transfer all or parts to the company.

(3) If TU and the company jointly hold any IPR, TU and the company shall enter into a joint application agreement or joint ownership agreement, which shall include the three following clauses:

   (a) TU may not exploit the IPR in any area outside of the research area;

   (b) The Company may exploit the IPR itself without the consent of TU;

   (c) The Company shall pay to TU all expenses paid by TU to file an application and maintain such IPR until the company enters into an agreement with TU, and shall pay all necessary expenses after the execution of such agreement;

Clearly, in the case of collaborative research, the industrial partner has a great deal of discretionary power over the invention. The overall tendency is that the university administration places much emphasis on collaborative research contracts, as they are an important source of research funding, future inventions and resulting patents. Besides, various measures have been undertaken to support the university-industry relations at Tohoku University: the university-industry liaison office has been strengthened, each department having administrative employees in charge of the liaison, and in some cases, hiring external professionals to facilitate UIR. All these elements show that industrial partners are actively involved in a large part of the patent portfolio of the university. This leads to the following interrogation: does this trend influence the productivity and research direction of the academics involved with the company as well? We address this question in the second part of this chapter.

2.2.3 Summary of the results

In the first part of this chapter, we have carefully described the legislative changes that took place recently to favor the university-industry relationship and to make more transparent IP rights. Collaboration and transfer of IP rights with the industry were present before the Incorporation, but in a rather informal way. Since 2004, universities have taken charge in the management of discoveries originating from their faculty members, as showed by the increasing number of university-owned patents. Partner companies are, however, still widely involved in the patenting activity of the university, as exemplified by the case of Tohoku University. In Section 2.3, we run two econometric exercises to evaluate what influence patenting has on publications, and what the determinants of IP activities are. In this analysis, we take into consideration the presence of the industrial partner, peer effects and the type of funding.

2.3 Econometric analysis: All about academic patent's influence

In the past few decades, universities and other public bodies have become more proactive in their attempt to transfer their scientific discovery. This trend has been analyzed extensively, leading some scholars to herald the coming of the entrepreneurial university (Etzkowitz 2003), and leading others to warn of the danger of enclosing the scientific commons (Heller and Eisenberg 1998). This phenomenon has created a demand for empirical evidence on that matter. As we already mentioned, this trend has been well documented for the US and major European countries, little has been documented about Asia. Our aim here to use data on a leading Japanese university, Tohoku university, to analyze the academic patenting on university researchers' behavior.

We examine individual determinants of academic patenting in cross-section and panel datasets of Tohoku University faculty members. One of our more salient results is to uncover a rather complementary effect between patenting and publication. Although consistent with previous findings in the literature, this research generates new insights on the effect of private and public funding, and gives evidence of an adaptation to the reforms by the youngest cohort of scientists. Section 2.3.1 presents the literature relevant to our analysis, with a focus on the influence of peers and financial variables in setting a research agenda. Section 2.3.2 presents a cross-section analysis of faculty members active during the period 2004-2007. Section 2.3.3 analyzes a panel of 178 faculty members.

2.3.1 Review of the literature and research question

The aim of this section is not to reiterate the work done in Chapter 1, but rather to add some valuable information that will lay down the foundations for the empirical analysis. First, we provide some evidence from the litterature on the relation between patent and publication. We then investigate the influence of peers on these variables. Finally, we present the potential effects of various sources of funding on these variables.

a. Patent and publication

The aim of this section is to explore the theoretically conceived dilemma that individual scientists face, namely the potential trade-off between basic research activities and those activities that are required to successfully develop and commercialize academic inventions. In commercial settings, basic research is often considered as a substitute for more applied works. Several observers have worried that a similar dynamic might be at work in universities, despite the fact that the majority of empirical studies found no evidence of a negative impact on patenting activities on publication output. We have already dealt with this subject in the literature review (Chapter 1). Instead, our objective is to precisely relate the aspects which are relevant to our inquiry and comment more thoroughly on some comparable works. The majority of studies focusing on the implication of university scientists in technology transfer activities centers on three kinds of data: patents and invention disclosures, licenses, and spin-offs. Such data is increasingly employed as it becomes more widely available. Patents can now be retrieved digitally in patent offices databases. This information is used as a proxy to measure technological transfer by universities. We use patent and publication data as the center of our analysis. We present below some of the major empirical findings.

Fabrizio and DiMinin (2008), using a matched panel sample of 150 patenting and non-patenting scientists across several US universities found a positive relationship between patenting and publishing. Azoulay et al. (2006) using a large sample of US life scientists found that patenting has a positive effect on the rate of publication of articles. They used the inverse probability of treatment weight to predict selection into patenting. In a recent study, using the same method on a sample of Max Plank Institute's directors in Germany, Buensdorf (2009) found results consistent with prior findings, that inventing does not adversely affect research output. Exploiting cross-sectional data from a survey of doctoral recipients, Stephan et al. (2007) found patents to be positively and significantly related to the number of publications. Carayol (2007) at the University Louis Pasteur in France, encountered similar results using cross-sectional data. The only major discording voice is the work of Agrawal and Henderson (2002) on a panel of MIT scientists. They found no evidence that patenting activity is significantly correlated to publishing activity.

The empirical evidence points, overwhelmingly, to the direction of a complementary relation. The logical question to ask is, therefore, why should we engage in a similar endeavor? The first response is that, until now, all the studies have been Americano-European centered. To our knowledge no similar research exists in the context of Japan or even Asia. This lack of data on Asia calls for research on that topic: Are there any differences due to different institutional settings, or do comparable results exist? The question calls for an answer. On top of this, we were able to construct a unique dataset on Tohoku University that we believe can be mobilized to better model the determinants of the relationship between patenting and publishing. We will now turn to two variables that should be taken into consideration while investigating the relation of patenting activities on publication output: influence of peers and financial variables.

b. Influence of peers

One important factor in determining whether a scientist is likely to engage in any technology transfer activities is the influence of peers in shaping his choice. Indeed, science is not a solitary quest, as it is often the result of collaborative works that are themselves the result of a given social structure. On the social level, the referee system in science involves the systematic use of judges to assess the quality of scientific research. The judges include editors and referees who assess the acceptability of manuscripts submitted for publication, experts who evaluate proposals for research grants, and peers who decide to cite, or not, a piece of work in subsequent publications. Moreover, science is a collaborative process in the making: far gone are the myths of the lonely scientist. Collaboration is increasingly viewed as a necessary step in the production of science. Corroborating this trend, Hicks and Katz (1996) have documented the upward proportion of papers involving collaboration to the detriment of non-collaborative papers. Many empirical findings point at the influence of institutional and contextual factors as important factors determining individual productivity. In a series of works, J. Scott Long and his colleagues (Allison and Long 1990; Long 1978; Long and McGinnis 1981) found that when a scientist is employed in a particular context, his productivity soon conforms to the particularity of this context. The mobility of scientists in prestigious departments increases their rate of publication and citation, while downward mobility to less prestigious departments decreases this rate. Carayol and Matt (2006) found that the intensity and quality of a colleague's research activities within laboratories are beneficial for individual research.

Concerning the propensity to engage in commercial activity, evidence shows that the institution one is in and the attitude of one's colleagues determine partially the rate of engagement with the industry and individual rates of patenting. Group norms regarding industry commitment differ across departmental context. While some researchers regard opportunities arising from technology transfer activities positively, others are more reticent and fear adverse effects on the freedom of research (Lee 1996). There is evidence that scientists who work closely with commercially inclined peers will be more likely to engage in the commercial transfer of their scientific research. Stuart and Ding (2005) found that faculty members were more likely to become commercially-inclined when they worked in university departments that employed other scientists that had previously ventured into commercial activities. They argue that two mechanisms are at play in the effects of colleague commercial activities on a scientist. First, it legitimates the undertaking by increasing the acceptance of this phenomenon. Second, it lowers the costs of collecting information on commercial sector activities. Bercovitz and Feldman (2008) pinpointed that when the chair of the department is active in technology transfer, other members of the department are also likely to participate. In the same line, Tartari et al. (2010) found that academics' engagement with industry is strongly influenced by their departmental peers' attitudes and behaviors. Individual are at least partially influenced by their localized social environment. All these studies indicate the influence of peers, particularly at the department level.

Hence, we focus our empirical analysis on the department level, as a complementary to the individual level, where scientific collaboration and peer pressure is high. Indeed, the department level is an important element of academic life. Working in a department imposes obligations and responsibilities on academic staff, such as defining teaching programs, sitting on committees, and the like. Hiring and promotion are normally decided at the departmental level. As such, the department generates a web of interaction and overlapping bonds of collegiality. It is a level of analysis where peer pressure is influential and shapes individual behavior. It plays an important role in determining the working behavior patterns and norms of academic life.

In our cross-sectional analysis, we test the influence of departmental colleagues' works on a scientist's propensity to patent. Building on the above references, we hypothesize that a researcher employed in a department inclined to patent will see his/her patenting activity become positively influenced by his/her colleagues' work.

c. Financial variables

Crow and Bozeman (1987) underline that the nature of the research (applied vs. basic) is strongly influenced by the funding structure of the laboratory. As such, financial variables are an important input of university research. On top of recurrent funding, a university researcher can seek additional funding through research grants, or work with the industry through joint research, contract research and consulting. Research funding is an important part of academic life: it is certainly a variable affecting the output of a researcher. Having access to additional research funds should therefore enhance outputs. Symmetrically, research funding can also be seen as an indicator of a researcher's capabilities and of the attractiveness of his/her work. Research grants are supposed to be awarded to the most promising projects. And, in the same way, industrial partners try to mate with the most prominent scientists in their field of expertise.

We believe that financial variables should be included in works interested in scientific output, as they convey information on the perceived quality of a research project and the means mobilized to achieve it. This is seldom done in studies focusing on the individual level: this type of data is complicated to obtain. With the exception of the works on University Louis Pasteur in France, (Carayol 2007, Carayol and Matt 2006), we are not aware of the inclusion of financial data in this type of research. We expect researchers' patenting and publication performance to increase with the total amount of funds received, and patenting to be positively associated with private funding. We hypothesize that research grants should mainly influence publication outputs and that contractual research should have a positive effect on patenting levels. In the next two sections, we move to the empirical part.

d. Research questions

The three above-mentioned elements will be used in the following empirical section. First, we will test the relationship between publication and patent, in both number and quality of publication output. We test also their sequential relation in our panel data analysis. From the literature, we hypothesize a positive relation between these two variables in term of quantity. As for quality the empirical results presented in the literature are more thin and we are not sure of the sign of the relation, if any. In terms of peer effects, we hypothesize a relationships between the activity colleagues within a department and an individual propensity to patent. This assumption will be tested in the cross-section experiment. Third, we hypothesize a relation between the patenting and publishing activity and the origin and amount of research funds a researcher receives. In the cross-section analysis, we test the influence of the patenting activity on research grants and contractual money, as well the existence of industrial sponsors. On top of that, in our regressions we control for age and research fields as these variables are likely to influence the outcome, especially since we are interested in seeing whether there are age differences in engaging into patenting. We believe that depending on the age cohort a researcher belongs to, the individual responses to a changing legal environment concerning university technology transfer may differ.

In Section 2.3.2, our econometric exercise is centered on a pooled cross-section analysis of 808 permanent academics at the Tohoku University from 2004 to 2007. This analysis starts in 2004, because we were able to access internal document on staff, patents, and research contracts from this date forward. Section 2.3.3 is based on a panel data setting of 178 academic inventors who were active in the university from 1994 to 2008.

2.3.2 Cross section analysis: Patent and publication activities of Tohoku University researchers

This section attempts to study the determinants of academic patenting using data on a large sample of Tohoku University academic researchers. We examine patenting at the individual level as opposed to the institutional level. Our aim is twofold: (1) to investigate the relationship between publishing and patenting; (2) to examine how patenting activity relates to individual and departmental characteristics. We first explain how we retrieve and organize the data. This is followed by a description of the sample (a & b). We then move on econometric specifications (c & d), present the results (e), and summarize the main findings (f).

a. Data

Data concerns the research activity at Tohoku University from 2004 to 2007. We decided to start our sample in 2004 as it corresponds to the Incorporation of Tohoku University. From this date onwards, national universities gained more independence and managerial freedom. One unintended favorable consequence of this policy change for our inquiry was an easier access to internal documents, as we could get access to the documents from the university without needing to ask the permission to the Ministry of Education (MEXT).

We were able to collect comprehensive data on 9 schools and institutes: the engineering part of the faculty (Graduate School of Engineering and Graduate School of Environmental Studies[9]), its attached research institutes (Institute for Materials Research, Fluid Science Center, Biomedical Engineering Research Organization, Research Institute of Electrical Communication), and the life and physical sciences related Graduate schools of the university (Graduate school of Science, Agriculture and Life Sciences). These schools and institutes represent a total of 1,156 permanent academic staffs and a total of 3,693 graduate students. Overall, the university groups 2,681 permanent academic staff and 6,585 graduate students.[10] We did not include in our analysis the humanities and social sciences disciplines, as they are not, in the large majority, involved in the patenting process. On top of that, we have deliberately omitted the University Hospital and Graduate School of Medicine, as we could not trace precisely the staff in these structures (many of them have different caps and affiliations and therefore are difficult to track down).

We collect and compile internal documents from three sources: the University Evaluation Center, the Center for Research Strategy and Support (CRESS), and the Human Resource Department. We received a list of all the academic staff on the university's annual payroll from 2004 to 2007 from the human resource department. We excluded from our sample all researchers who were not included in this list so as to ensure that all individuals considered were present over the whole pe-

[9] It was established in April 2003, the overall majority of the members came from the School of Engineering.

[10] The figures are for 2007.

riod. Only 808 scholars remained in our sample. This big drop in the number of researchers finally included in our sample can be explained by the fact that some researchers retired, some of them left the university, and others arrived during the period under study. The documents we collected provided us with a wide range of information about each researcher in our sample. We were able to compile the following individual characteristics on each one of them: sex, age, title, affiliation,[11] and whether they were employed in a teaching and research position or strictly research.

Dependent variable

Our sample represents the lion's share of the scientific research and patenting of the university. Indeed the university is historically strong in the engineering and sciences fields. For the purpose of our analysis, we use the number of patents on which a researcher is listed as an inventor in our four-year period as an indicator of patenting activity. We listed the entire patent applications received by the Intellectual Property Office for the period 2004-2007. These are mainly university-owned patents. For each one of these patents, we know who the inventors were, and whether they were part of the university or not. We use these indicators as a proxy to evaluate the involvement of a researcher in patenting activities. Each time an inventor is listed on a patent as an inventor (or applicant) adds to his/her patent count. This is our dependent variable. For simplicity, we refer to it as *Patent*. We do not make any distinction between national and international patent applications as we see it as an external factor for the researcher. In most cases, the university, not the researcher, is the applicant.

Independent variables

To measure publication trends, we rely on two bibliometric indicators: the quantity of the publication output (measured by publication counts), and the quality of the publication output (measured by citations to the journal it was published in). Information on the published articles of each researcher was collected using the Science Citation Index (SCI) databases provided by Thomson Reuters.[12] This database is often used in empirical studies on the subject. For each researcher in

[11]By affiliation, we mean which department the researcher belongs.

[12]For more information consult: http://www.isiwebofknowledge.com/.

our sample, we checked the number of publications referenced in the SCI database for the period 2004-2007. Because of the high frequencies of homonymy in Japanese surnames, when in doubt, we double-checked the results retrieved through the database with internal documents.[13] We have decided to take into account the rough number of publications as we have not tried to correct this number by co-authorship, i.e. papers published with five authors or with two authors are considered to be equal. We refer to this variable as *Paper*. Some studies weigh publications by the number of co-authors, but we feel that this approach is intrinsically flawed. Should the effort of a publication written by three co-authored be divided by three? Does every co-author put the same effort and time in a paper? Does the position in the publication record matter? Do the first and the last authors of a publication carry the same weight in the writing process? With no credible answer to these questions, we argue for the use of a simple count procedure for publications.

In order to account for the quality of a publication, we assign a weight to each one of them corresponding to the impact factor of the journal it was published in. The impact factor of an academic journal is an indicator that reflects the use by the community of the articles published in this journal: the higher the impact, the higher the reputation and diffusion of a journal.[14] This information enabled us to weigh a publication by a measure representing a theoretical impact, and hence to create a performance indicator (*Paper Impact*).

Control variables

We include in our model a range of control variables. The first group of control variables, as it is common in such studies, relates to the individual features of the academics. We include researchers' academic characteristics such as the academic rank (coded as a dummy variable *Professor*) and the existence of teaching duties (*Teaching*). We also record the age of the researcher.

On top of that, we control for the amount of research funds received by a researcher. We gathered internal financial data with the help of the Center for Research Strategy and Support (CRESS). We include two types of funds: research

[13] A list of the university researchers' publications is available on http://db.tohoku.ac.jp

[14] For 2007 the impact factor of a journal is calculated as follow: 2007 cites to articles published in 2006-5 divided by the number of articles published in 2006-5.

grants and contractual funding. For the first one, we incorporate data on Grant-in-Aid for Scientific Research, which is referred to as *Grant*. These grants support research projects submitted on the initiative of the researcher. They cover the full spectrum of scientific research fields from the humanities and social science to natural science. They are an important policy tool of the government to support high level scientific projects. They represent about 37% of total competitive research funding for universities, and therefore are larger than any other programs.[15] Research grants can be applied to one, or several researchers. Our data is limited to the principal investigator, the person in charge of implementing and managing the project, as opposed to the co-investigator who is not given autonomous use of the grant funds. We define the variable Grant as the total amount of research grants a principal investigator received for the project. If the project lasted for several years, we have data on the amount of research funds for every single year. For contractual funding, we create a variable, *Contract*, gathering contractual, commissioned research, and consulting activities. On top of that, we control for the origin of the funds, whether public or private, by generating a dummy variable *Priv.contract*.

A second group of variables are related to each department's characteristics. Our 9 schools and institutes include 65 departments. As discussed in the literature review section, we focus on the department level to gauge colleagues' influence on a researcher's work. One possible caveat of such a level of analysis in the Japanese context is that, historically, the chair system, named *kouza*[16] in Japanese, was very strong in Japanese universities. Chair holding professors had near complete authority with regard to decision-making, and the collaboration between chairs in teaching and research was not the rule. For these reasons, departments may not be the best level of analysis. However, over the last decade, the research organization of universities has evolved. It has moved toward a "large" chair system - *Daikoza-sei* in Japanese. The result of this was that an original chair, which consisted of few professors, associates and assistant professors, was amalgamated with other

[15]Numbers for 2002, source MEXT website: www.mext.co.jp

[16] A *kouza* typically consists of one full professor, the laboratory head, one associate professor, and an assistant professor. The system was modeled on the early twentieth-century German university system of professor chair.

chairs. As noted by Ogawa (2002), the direction of these reforms suggests a move toward a department system common in the US. Therefore, we feel confident to perform our analysis at the department level.

To compute the characteristics of each researcher's colleagues, we take into account all the permanent researchers of a department and exclude the researcher who is analyzed.[17] *Dept.paper* gives the number of publications of departmental colleagues. The variable is corrected for co-publications within a department: if more than two researchers co-authored a publication, it is only counted once. The quality of a colleague's publications is proxied by*Dept.Impact*, which corresponds to publication performance of colleagues corrected by impact factor. *Dept.Size* stands for the number of academic staff being employed in a department.[18] Finally, we include dummies for research fields. Unfortunately, for the researchers or even the departments, we could not find precise information characterizing their field of research. We therefore had to find a way to create a discipline dummy variable. To do so, we decided to compile all the publications of each department for our period of inquiry. We based our measure on the fact that each paper is published in a journal that is classified in one of the ten research fields of the SCI database (classification Level 1[19]). For each department, we looked at which field it publishes the most in, and used this category to brand the main field of expertise. We decided to create this variable as it is, in our view, a good way to measure in which field the members of a department were the most active for our period of inquiry.

b. Sample description

Summary statistics of the variables are presented in Table 2.3. Firstly, it is valuable to notice that the average level of publication is overwhelmingly higher than the patent one. The foremost output of an academic researcher is his/her publications. On top of that, as often seen in such studies, the distribution of the variables is very uneven. Both the patent and paper measures appear highly skewed, as shown in Figure 2.6. The distribution of patents is considerably more skewed,

[17] We used the complete set of 1,156 academics to compute these variables.
[18] As the number fluctuated over the period for some departments, we record the size in 2007.
[19] Confer to Appendix B for more details.

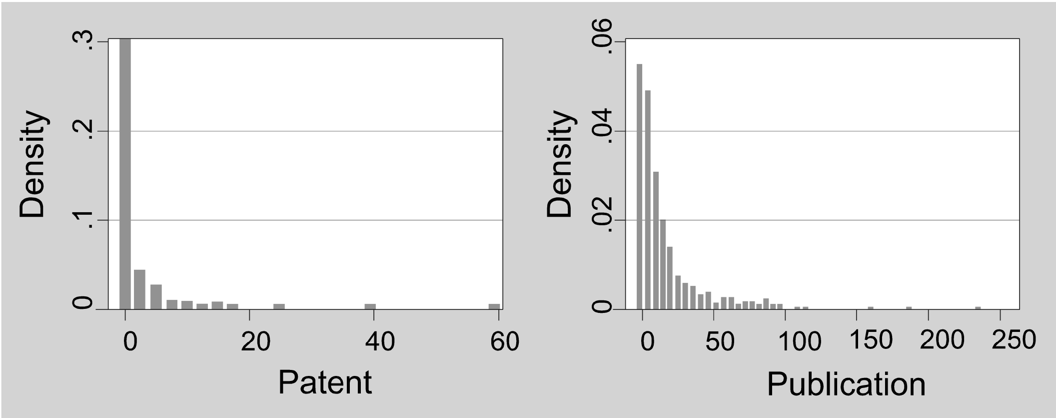

Figure 2.4: Histogram of patents and publications

Table 2.3: Descriptive statistics

	Mean	Median	Std. Dev.	Min	Max
Patent	1.28	0	3.65	0	61
Paper	13.21	7	19.68	0	225
Paper Impact	27.91	11.62	49.49	0	601
Grant	289	79	635	0	6822
Contract	153	0	553	0	8813
Ind.Contract	0.28	0	0.45	0	1
Lab.Paper	214	164	178	0	868
Lab.Impact	466	326	480	0	2196
Lab.Patent	15.51	6	23.84	0	104
Lab.Grant	6619	4671	5801	0	23941
Lab.Contract	2920	2846	2377	0	9862
Teaching	0.78	0	0.41	0	1
Prof	0.38	0	0.49	0	1
Age [25-35]	0.19	0	0.39	0	1
Age [36-45]	0.35	0	0.48	0	1

however, than that of publications. Table 2.4 shows the degree to which patents and publications are related, by examining the joint distribution of patents and article counts. Overall, 102 researchers have no patents or publications in our period of analysis, while 231 have both. These figures account for respectively 13% and 29% of our sample. We see that the large majority of researchers who are the most active patentees are also active in publishing. It is possible to infer from this evidence that these two activities might go hand in hand, especially among the most prolific and versatile researchers. Further analyses are needed to confirm this conjecture.

We see from Table 2.3 that the average amount of research grants is superior to the average amount of contractual funding. In term of private partnership, 28% of our sample has been engaged, at least once, in a research contract with a corporate partner. As for research fields, engineering and physics account for a bit more than half of the sample.

c. *Econometric specifications*

Our outcome of interest, the number of patents, is a non-negative integer or count. Because the response variable is discrete, its distribution places probability mass at non-negative integer values only. The natural starting point for an analysis of counts is the Poisson distribution and the Poisson model. The univariate Poisson distribution has the following probability mass function:

$$Pr[Y = y] = e^{-\lambda}\lambda^{y}/y! \quad , \qquad y = 0, 1, 2... \tag{2.1}$$

Table 2.4: Patent and publication distribution

Patent	0	1-5	6-10	1-61	Total
Publication					
0	102	13	2	1	118
1-5	196	42	2	0	240
6-10	96	37	3	5	141
11-225	167	102	29	11	309
Total	561	194	36	17	808

where λ is the intensity or rate parameter. The two first moments are:

$E[Y] = \lambda$ and $V[Y] = \lambda$

This shows the well-known equality of mean and variance, also called the equidispersion property of the Poisson distribution. In empirical works, the equidispersion property is often violated, as overdispersion of the data is common. Indeed, overdispersion in count data may be due to unobserved heterogeneity. In that case the conditional variance exceeds the conditional mean. One way to account for overdispersion is to use the negative binomial specification. In such a setting, counts are viewed as being generated by a Poisson process but it is not possible to correctly specify the rate parameter, λ, of the process. Instead, the rate parameter is itself a random variable. If the parameter λ is random, rather than being a completely deterministic function of regressors, then the negative binomial model is used. A way to choose between the two models is to run a formal test of the null hypothesis of equidispersion, $Var(y/x) = E(y/x)$, against the alternative of overdispersion. This test can be can based on the following equation:

$$V(y/x) = E(y/x) + \alpha^2 E(y/x) \tag{2.2}$$

which is the variance function for the negative binomial model. We test $H0 : \alpha = 0$ against $H1 : \alpha > 1$. We run this test on our data to see whether we are in the presence of overdispersion. The null hypothesis was rejected.

Additionally, our data presents some other particularities that we have to take into account if we want to model our process correctly. Our dependent variable, *Patent*, is heavily skewed to the right, with a high proportion of zero values. Natural candidates for such data are Zero-Inflated Poisson or Zero-Inflated Negative Binomial models (ZIP, ZINB). These models enable us to deal with the fact that the data displays a higher fraction of zeros, or non-occurences, unlike standard count regression models. The zero-inflated model combines a binary variable c with a standard count variable y^* (with support over the nonnegative integers) such that the observed count y is given by:

$$y = \begin{cases} 0 & \text{if } c = 1, \\ y^* & \text{if } c = 0. \end{cases} \tag{2.3}$$

If the probability that $c = 1$ is denoted by ω, the probability function of y can be written compactly as:

$$F(y) = \omega d + (1 - \omega)g(y) \quad , \qquad y = 1, 2, 3... \tag{2.4}$$

Where $d = 1 - [\min \text{y}, 1]$ and $g(y)$ is a regular count data probability function such as the Poisson or the negative binomial function. The advantage of this formulation is that it can account for two types of zero outcomes. Indeed, zero outcomes can either arise from regime 1 ($c = 1$) or from regime 2 ($c = 0$ and $y^* = 0$).

The question then is whether the characteristic assumption of zero-inflated models, namely two types of zero outcomes, is theoretically appealing or not. In our analysis we are interested in patent applications. It can be argued that a scientist may not be listed on a patent for two reasons: he did not attempt to or he did not have the opportunity. For instance, there are academics that are not interested in applying for a patent, regardless of whether or not some of their research may be patentable. On the other hand, there are academics that are involved in patenting activities, but they may not patent in a given period if the opportunity does not arise. This interpretation sounds quite appealing in explaining different types of zero outcomes, and therefore, we decide to use zero-inflated models.

Following Lambert (1992), we specified a logit model for ω in order to capture the influence of covariates on the probability of extra zeros. For a more in-depth analysis of the treatment of zero in count data models, it is possible to refer to Winkelman (2008) and Cameron and Traverdi (2005). It should to be noted that one of the weakness of our approach in estimating the influence of publications on patents is the potential correlation between publication and unobserved heterogeneity among our scientists. One way to solve this shortcoming would be to use some instrumental variables,[20] but we could not think of any in our setting.

[20] A variable z is called an instrument or instrumental variable for the regressor x in the scalar

Despite this shortcoming, we are confident to have used the appropriate methodology to analyze our data.

d. Estimation methodology and test

In this section, we report the result of the different tests that were implemented to justify the models we used for our estimations. First of all, a brief look at the data indicates the presence of overdispersion, indeed our dependent variables have a variance superior to its mean $(Var[yi] \geq E[yi])$. A formal test was conducted to test for overdisperion. The null $H0 : \alpha = 0$ was rejected, it indicates the presence of significant overdispersion. Thus a simple Poisson model would not be appropriate. Such a phenomenon may be due to two non-exclusive phenomena: unobserved individual heterogeneity and/or zero inflation. In fact, together the zero inflated Poisson model (ZIP), the Negative Binomial (NB) model and the ZINB model are natural candidates for us. The ZINB appears to be preferable to the ZIP model which is nested in it, our variables presenting overdispersion.

Table 2.5: Information criteria

Negative Binomial (NB)			Difference	Prefer
Vs.	BIC	= -3135	dif. = -61.514	NB
Zero Inflated NB	AIC	= 2.386	dif. = 0.058	ZINB
ZINB	Vuong	= 5.179		ZINB

A standard measure to choose between nonnested models is to use information criteria. They are log-likelihood criteria with degrees of freedom adjustment. The model with the smallest information criterion is preferred. The main intuition behind this is that there exists a tension between the model fit, as measured by the maximized log-likelihood value, and the principle of parsimony that favors a simple model. The fit of the model can be improved by increasing model complexity. However, parameters are only added if the resulting improvement in fit sufficiently compensates for loss of parsimony. Two standard measures are Akaike's information criteria (AIC) and Schwarz's Bayesian information criteria

regression model $y = \beta\, x + u$ if (1) z is uncorrelated with the error u and (2) z is correlated with the regressor x.

(BIC). Smaller AIC and BIC are preferred. It is also possible to test one nonnested likelihood-based model against another using the LR test of Vuong (1989). We have compared NB and ZINB specifications using these three criteria. Results are displayed in Table 2.5.

The BIC, which penalizes model complexity (the number of parameter estimated) more severely than the AIC, favors the NB model, whereas the AIC favors the ZINB model. The positive value of the Vuong statistic is in favor of the ZINB model. We compared the actual versus the predicted probability of the different events from 1 to 9. Both models were close to actual frequencies.[21] All together ZINB seems to allow a slight improvement over the NB, as shown by the information criteria, but it comes with a price of greater complexity. We will therefore present results for both ZINB and NB models.

Finally, interest often lies in measuring marginal effects, the change in the conditional mean of y when regressors x change by one unit. For the linear regression model, $E[y|x] = x'\beta$ implies $\partial E[y|x]/\partial x = \beta$ so that the coefficient has a direct interpretation as the marginal effect. For nonlinear regression models, this interpretation is no longer possible. For example, if $E[y|x] = exp(x'\beta)$, then $\partial E[y|x]/\partial x = exp(x'\beta)\beta$ is a function of both parameters and regressors, and the size of the marginal effect depends on x in addition to β. In order to have a better interpretation of the coefficient we will present the marginal effects at the mean of the dependent variable (Table 2.6).

In our estimation we have used robust standard errors in order to adjust for heteroskedasticity in the model and further adjusted them to take into account the clustering implied by the 65 departments.

e. Results

Table 2.7 displays the results. The ZINB models (given in Eq. 3) have two components: the negative binomial part accounts for the numbers of patents invented when individuals are in the patenting regime, whereas the logit zero inflation part explains the switch between the patenting and the non-patenting regimes. Let us

[21] We used the user-written countfit command in STATA to calculate the frequencies.

Table 2.6: Marginal effects at the mean of the dependent variable

	Model 1a dy/dx		Model 1b dy/dx		Model 2a dy/dx		Model 2b dy/dx		Mean
Paper	0.026	**	0.026		0.017	**	0.030	**	13.52
Paper Impact	-0.003		-0.003		-0.002		-0.005		28.57
Grant	7.02e-05	*	1.21e-05		7.59e-05		2.76e-04		293.19
Contract	3.74e-04		4.85e-04		3.71e-05	*	1.60e-03		157.84
Ind.Contract	1.171	***	0.878	**	0.734	***	0.522		0.28
Lab.Paper					0.004	*	0.006		217.87
Lab.Impact					0.010	**	0.015	**	16.03
Lab.Grant					-2.87e-05		-4.18e-05		6692.62
Lab.Contract					-1.39e-05		1.98e-05		3002.95
Teaching	0.182		0.133		0.133		0.123		0.777
Prof	0.044		0.085		0.152		0.143		0.379
Age [25-35]	1.413	**	1.421		1.014	*	0.680		0.186
Age [36-45]	0.415		0.216		0.375	*	0.025		0.346
Age [46-55]	0.025		0.064		0.089		-0.115		0.268
Physics	-0.597	*	-1.053	**	-0.158		-0.387		0.259
Mat.Science	-0.112		-0.159		0.400		0.994		0.078
Chem.	-0.292		-0.654		0.129		-0.293		0.102
BioChem.	-0.112	***	-0.687		1.004		0.248		0.060
Earth.Science	-0.770		-1.304	***	-0.543	***	-0.951	***	0.055
Biology	-0.368		-0.493		0.082		0.371		0.142
Chem.Eng	-0.013		0.381		0.442		1.405		0.013

Notes: (1) The coefficients of age and discipline variables should be understood in comparison with Age > 55 and Engineering dummy variables which are taken into reference.
(2) Monetary accounts are expressed in 1,000th of dollars, the following exchange rate was used ¥120= $1
(3) * Significant at 5%, ** significant at 1%, *** significant at 0,1%.

note that a positive coefficient in the zero inflation part of the model means a higher chance to remain in the non-patenting regime, which implies zero patent. By using this model, we attempt to capture the difference between scientists who are not involved in patenting because they are not interested, and scientists who are interested but do not necessarily participate in IPR activities during the period under study. The results of the negative binomial specification are provided as well. The marginal effects for the four models computed at the mean of the independent variables are presented in Table 2.6. Finally, we left out from our analysis 24 individuals belonging to a department specialized in mathematics from our analysis as they did not trigger a single patent during the period of inquiry (in general, pure mathematical concepts are not patentable). Our first major series of findings tell us

Table 2.7: Results of the regressions with Patent as the dependent variable

Dependent variable	Patent		Patent			Patent		Patent			
	Model	1(a)	Model	1(b)		Model	2(a)	Model	2(b)		
	Neg Bin		ZINB			Neg Bin		ZINB			
			Neg Bin		Logit			Neg Bin		Logit	
Paper	0.035	**	0.021	*	-0.287	0.028	**	0.021	*	-0.028	
	(0.012)		(0.009)		(0.681)	(0.011)		(0.009)		(0.030)	
Paper Impact	-0.004		-0.003		0.068	-0.003		-0.005		-0.004	
	(0.004)		(0.004)		(0.2)	(0.005)		(0.004)		(0.014)	
Grant	9.88e-04		-2.94e-06		-4.77e-03	1.26e-04		-1.10e-05		-0.002	*
	(9.18e-04)		(8.77e-05)		(1.46e-02)	(8.59e-05)		(8.97e-05)		(0.001)	
Contract	5.27e-04	*	3.53e-04	**	-2.29e-02	5.72e-04	*	3.28e-04	**	-0.006	
	(2.28e-04)		(1.22e-04)		(4.48e-02)	(2.37e-04)		(1.12e-04)		(0.005)	
Ind.Contract	1.199	***	0.641		-1.822	0.906	***	0.108		-2.279	**
	(0.218)		(0.580)		(2.945)	(0.202)		(0.210)		(0.712)	
Dept.Paper						0.010	**	0.005		-0.015	*
						(0.003)		(0.004)		(0.008)	
Dept.Impact						-0.004	**	-0.002		0.007	*
						(0.001)		(0.002)		(0.003)	
Dept.Patent						0.013	**	0.010	*	-0.012	
						(0.005)		(0.005)		(0.009)	
Dept.Grant						-2.54e-06		-1.88e-05		6.69e-05	
						(3.59e-05		(3.42e-05)		(9.60e-05)	
Dept.Contract						-2.81e-05		5.04e-05		1.76e-05	
						(4.56e-05)		(6.66e-05)		(1.64e-04)	
Dept.Size						-0.019		-0.011		0.023	
						(0.011)		(0.008)		(0.025)	
Teaching	0.274		0.116		-0.548	0.201		-0.048		-0.796	
	(0.189)		(0.253)		(1.167)	(0.186)		(0.161)		(0.429)	
Prof	0.061		0.078		1.543	0.352		0.316		0.756	
	(0.312)		(0.323)		(3.598)	(0.286)		(0.266)		(0.591)	
Age [25-35]	1.256	***	0.891	*	-0.068	1.143	***	0.189		-1.847*	
	(0.338)		(0.450)		(1.962)	(0.325)		(0.354)		(0.875)	
Age [36-45]	0.531		0.181		0.329	0.610	*	-0.084		-1.366	
	(0.271)		(0.279)		(2.245)	(0.274)		(0.276)		(0.803)	
Age [46-55]	0.034		0.069		2.402	0.298		-0.025		-0.273	
	(0.244)		(0.292)		(5.804)	(0.232)		(0.255)		(0.876)	
Physics	-1.031	*	-1.124	**	-0.578	-0.446		-0.547		-0.693	
	(0.415)		(0.429)		(3.522)	(0.269)		(0.300)		(0.744)	
Mat.Science	-0.169		-0.144		0.042	0.472		0.677	*	0.343	
	(0.413)		(0.433)		(2.291)	(0.326)		(0.264)		(0.884)	
Chem.	-0.494		-0.736		-0.383	0.262		-0.349		-1.417*	*
	(0.526)		(0.544)		(0.659)	(0.303)		(0.343)		(0.617)	
BioChem.	-0.169		-0.832		-13.721	1.008*	*	-0.106		-15.113	
	(0.435)		(0.534)		(7.431)	(0.466)		(0.508)		(11.022)	
Earth.Science	-2.729	***	-2.990		-1.553	-1.900	***	-1.257	***	1.315	
	(0.464)		(3.398)		(24.018)	(0.505)		(0.370)		(1.017)	
Biology	-0.639		-0.498		0.898	0.128		0.362		0.459	
	(0.595)		(0.726)		(2.304)	(0.496)		(0.367)		(0.801)	
Chem.Eng	-0.017		0.297		1.822	0.357		0.787	**	0.936	
	(0.363)		(0.383)		(2.754)	(0.324)		(0.385)		(0.869)	
Constant	-1.225	*	0.000		1.636	-1.801	***	0.015		2.749	*
	(0.616)		(1.024)		(1.409)	(0.516)		(0.481)		(1.268)	
alpha	2.880	***	1.781	***		2.411	***	1.198	***		
	(0.489)		(0.634)			(0.324)		(0.229)			
Log pseudo-likelihood	-962.896		-918.113			-931.331		-887.351			

Notes: (1) The coefficients of age and discipline variables should be understood in comparison with Age > 55 and Engineering dummy variables which are taken into reference.
(2) Monetary accounts are expressed in 1000^{th} of dollars, the following exchange rate was used ¥120= $1
(3) * Significant at 5%, ** significant at 1%, *** significant at 0,1%.

more about the effect of publication related variables. We find a positive and significant relation between patenting and publishing in all our model specifications. The marginal effects are positive and strongly significant in models 1(a), 2(a) and 2(b). Accordingly, these two activities show recurrent signs of complementarity. Hence, we can confirm in our setting a positive patent-publication relationship as suggested in previous studies. This give weight to the idea that these two types of output are the two sides of the same coin: depending on the nature of scientific results, knowledge flows through one or two channels (More on this in Chapter 5). If our analysis stopped here, it would be of limited use either practically or theoretically. This is why, when designing our research setting, we have added many control variables, some widely used in the literature, some more idiosyncratic to our rich dataset.

We calculate the influence of publication corrected by its impact. The previous finding does not hold if publications are weighed by the impact factor of the journal they were published in. The variables *Patent* and *Publication impact* are negatively correlated, but this is not significant at the individual level. The story looks a bit different if one considers the quality of the journal in which the articles are published. At the department level, in model 2(a), the number of publications by fellow members of the department are positively correlated to the dependent variable (marginal effects go pairwise), whereas colleagues' publications corrected by impact are negatively correlated with patenting. Moreover, in the specification 2(b), the publication impact coefficient of the zero-inflated part is positive and significant. Therefore, the quality of the department publications affects the probability of a researcher to stay in the non-patenting regime. We can see in this tendency a kind of specialization, with some departments putting more focus on publishing in high quality journals and some others conducting research related more to patenting outcomes. This result gives credence to our hypothesis that research is a collaborative process. Taking place at the departmental level, a scientist research endeavor being woven to the work of his immediate colleagues. A peer effect is clearly emerging. This will be confirmed by other variables.

On a more direct relation, the level of colleagues' patents positively affects a researcher's propensity to patent: coefficients are positive and significative under negative binomial and ZINB specifications. Marginal effects are positive and significant. Patenting and working with the industry are skills that differ from the traditional research repertoire (Owen-Smith and Powell 2001). Applying for a patent is a lengthy and complicated process. Learning from colleagues how to decipher the arcane of application procedures can facilitate and encourage individuals to engage in such an activity. On top of that, colleague's patentable research projects can plant the seeds for one's own research projects. Once again, we see the influence of a platoon of sharp colleagues active in a field of expertise.

Let us now focus on the financial characteristics. The amount of research contracts that a scientist manages has a positive and significant impact on all models. As for the dummy for funds originating from industrial partners, it is positive in models 1(a) and 2(a), and is negative in the logit part of model 2(b). The marginal effects support these results. The magnitude of the coefficients is quite large as well. The Binomial coefficient on *Priv.Contract* implies that, other factors being equal, the expected number of patents for a research having at least an industrial contract is about two times higher than for the other scientists. Moreover, getting contractual funding from the industry positively affects the probability to reach the patenting regime. Results from University Louis Pasteur in France reveal similar trends. Carayol (2007) found that laboratory contractual funding, and the share of it coming from private sources, increases the probability to patent. In our framework, colleagues' contracts do not affect a researcher's propensity to patent. This difference may be due to the difference in the data: they collected data on the laboratory level, whereas we had access to individual level data. The amount of research grants is only significant in the inflated part of model 2(b). Having more research grants influences the propensity to stay in the non-patenting regime. From these results, we see a clear influence of financial variables and a clear distinction between the effect of research grants and research contracts. The former has no visible influence on the propensity to patent. At the least, it encourages researchers to stay in the non-patenting regime. The latter has a positive impact on the patenting activity, to an even greater extent if the funds come from private partners. The question, then, is whether contractual funding goes to professors who are active in application-oriented research or if faculty members have engaged in marketable research to shore their works with additional funds. We address this question with more qualitative data in Chapter 4.

Concerning the control variables, neither the dummy variable controlling for teaching activities nor the one accounting for the academic rank, *Professor*, affect the dependent variable. The *Age [25-35]* dummy variable, the youngest group, correlates positively with patenting in three out of four of our regressions. Marginal effects are positive for this group. We test this result with some other specifications. We made age groups of equal proportions, each group having the same number of people. The results are similar. The youngest group is more active in comparison to the older one. We tried, as well, using the age as the control variable, the coefficients are negatives in models 1(a&b) and 2(b).[22] The results do not confirm the belief that patent productivity increases over the lifetime (Ledebur 2009). These results contrast with the ones from the University Louis Pasteur (Carayol, 2007) and a sample of American life scientists (Azoulay, 2006). One explanation to these results lies in the fact that the changes of university policy were quite new: the younger researchers might be more prone to integrate patents in their research practices. Lastly, the dummy variable for discipline unveils important differences among specialties. In comparison to the engineering disciplines, physics and earth sciences depict negative tendencies.

f. Summary of the main findings

This analysis has brought three clear-cut results. First, we found a positive relation between the number of patents and publications a researcher produces. However, when we take into account the impact of the publication, no correlation appears. This suggests that productive researchers can combine both activities. Quality of publication does not seem to have an influence on the patenting output. We also showed that the origin and amount of research funds that are managed

[22] We do not report the results in the text, as it would be too tedious. Results can be provided on request.

by faculty members has an influence on the patenting output. Traditional research grants do not seem to influence the patenting activity. However, research contracts, which are more directed towards applications by definition, have an effect on patenting activity, as well as on the type of partners of these contracts. Having worked with an industrial partner influences positively the patenting output.

Second, the output of colleagues working in the same department influences one's propensity to patent. The number of colleagues' publications positively affects a research patenting level as well as their patenting activity, while the quality of their publications has a negative impact. From these results, we can argue that the type and quantity of a researcher's colleagues influence his own productivity and type of research.

Third, we found that the younger cohort of researchers were more actively engaged in patenting activity than their older peers, reflecting a better adaptation to the new legal environment more prone to technology transfer activities as a core mission of an academic researcher. In the next section, we run regressions on a panel of university scientists which will generate complementary information to these results.

2.3.3 A panel data analysis: The case of a group of early patent adopters

This section aims at completing the previous one by using a panel data framework. Using panel data instead of cross-sectional data enables us to enrich our analysis by introducing a time dimension and to control for individual heterogeneity. Our data consists of a 15-year sample of academic scientists from Tohoku University. One difficulty encountered in our analysis was collecting data on patenting for such a relatively extended period. Indeed, as we have demonstrated in the first part of this chapter, before the Japanese Bayh-Dole Act and Incorporation of national universities, university-owned inventions occurred very rarely. In order to circumvent this issue of measurement, we used invention disclosure reports of the pre-incorporation period to monitor researchers active in IP activities before 2004. This enabled us to constitute a panel of 178 scientists from 1994 to 2008.

In this section, we question to what extent and in which direction faculty patenting affects the rate of production of scientific output. We first explain how we retrieved and organized the data (a). This is followed by a description of the sample (b). We, then, present the main results (c), and conclude with a summary of the main findings (d).

a. Data

The empirical analysis relies on a sample of university scientists who have patented at least one of their research results. To explore our hypotheses, we draw upon a unique dataset we created by compiling information from multiple sources. One of the major difficulties of our endeavor was to collect data on patenting, as the majority of academic patents before 2004 were invented by university researchers, but applied for by corporate partners. University-invented patents, unlike university-owned patents, are notoriously difficult to identify in patent databases. For several European countries, the KEINS project mitigated the problem by collecting and using government listings of university researchers to search patent documents (Lissoni, et al. 2007). Unfortunately, we do not have knowledge of such documents for the Japanese context. However, we were fortunate enough to stumble across the work of Kanama and Okuwada (2007) who conducted research on patenting at Tohoku university. Despite the very low level of university-owned patents before 2004, they attempted to verify whether or not some university-invented patents were filed before this date. To undertake this task, they obtained data from the university on all the researchers who reported at least one invention disclosure during the 1993-2004 period. In doing so, they were able to spot who was active in technology transfer activities. They recorded 348 individuals who reported at least one invention disclosure. Using the names of these individuals, they searched the Japanese Patent Database in the inventor section for patents applied from 1993 to 2004.[23]

We built upon this database. First, we restricted the sample to the faculty who were still on Tohoku University payroll in 2008. We were left with 264 individuals.

[23]Search was performed using the Intellectual Property Digital Library (IPDL) from the Japanese Patent Office.

Then, using various Internet searches,[24] we restricted our sample to the scientists who were in the university in 1994. None of the researchers who had reported an invention disclosure in 1993 were still in the university in 2008. Finally, we were left with 178 individuals who were in the university from 1994 to 2008. We wanted to have only scientists who were present during the entire period under study to be sure of their professional address while searching patent documents. Before 2004, the majority of the patents were applied outside the university. Therefore, our only way to spot someone in a patent document was to use his/her professional address. Concerning these 178 researchers, we use the data from Kanama and Okuwada (2007) for the 1994-2004 period. We just recoded the years as we switched from publication year to application year. We preferred to use the application year, as it is closer to the actual research and free from legal considerations that might make the time elapsing from application to publication among patents vary. We thereafter performed a manual search on these researchers for the years 2005 to 2008. We complemented this data with internal documents for the more recent patent applications, as some of them, especially for 2008, might not be publicly available yet.

As in the previous sections, information on the published articles of each researcher was collected using the Science Citation Index (SCI) databases provided by Thomson Reuters.[25] For each researcher of our sample, we checked the number of publications referenced in SCI for the period 1994-2008. Because of the high frequencies of homonymy in Japanese surnames, we have double-checked our results with internal documents.[26] For control variables, we included research grants. As we could not have information from the university before 2004 on this variable, we retrieved them from the Grant-in Aid for Scientific research Internet database.[27] One advantage of this database over internal documents is that it provides research reports for all the projects. Research reports are mandatory while applying for such grants and are publicly available. As in the previous section

[24] We searched for curricula, affiliation in publications, and research grants documents to accomplish this task.

[25] For more information consult http://www.isiwebofknowledge.com

[26] A list of the university researchers' publications is available on http://db.tohoku.ac.jp

[27] http://kaken.nii.ac.jp

(2.2.2), we limited our retrieval of data to the case where the researcher was the principal investigator. In that case, he has the charge to implement and manage the project, as opposed to the co-investigators who are not given autonomous use of the grant funds. [28] We define the variable *Grant* as the total amount of research grants received for a project. In the case of a project spanning for several years, we include data on annual research funding. The maximum time frame for grants labeled "scientific research projects on priority areas" is 6 years. Finally, we count the number of research grants a scientist had in a given year to account for the dynamic of researcher works: the more projects being run in a given period, the wider the potential opportunities. We labeled this variable *Grant Count.*

In order to control for the effect of age in the publication and patenting activities, we include the Age variable of the researcher in our analysis. Finally, we checked if our researchers were promoted during the 1994-2008 period, and created a dummy variable, *Promotion*, that takes the value one if promotion occurred in our timeframe.

b. Sample description

Table 2.8: Descriptive statistics

-	Observation	Mean	Std. Dev.	Min.	Max.
Paper	2655	6.77	6.81	0	88
Patent	2655	1.21	2.49	0	27
Grant	2655	3.15	6.62	0	125.97
Grant Count	2655	1.04	0.98	0	6
Promotion	2655	0.05	0.23	0	1
Age	2655	44.46	8.17	25	65

Table 2.8 provides summary statistics for the variables used in the analysis. Figure 2.5 displays patenting and publishing rates over time. Three elements are worth commenting on. First, publishing is a much more important activity than patenting – this is similar to what was found for MIT by Agrawal and Henderson

[28]Our choice is supported by the research reports published at the end of the grants. Theses reports show the central role of the principal investigator. Indeed, we examined the research reports of our most prolific scientists. We noticed that the principal investigator was nearly always included in them.

(2002). Second, both publishing and patenting rates increase significantly over the period. The patenting rate increases steadily until it reaches a plateau in 2003. The publication rate increases steadily the first few years as well. This trend can certainly be explained by fact that few faculty in our sample started their academic career in the first year. Their productivity increased over time along with career opportunities.

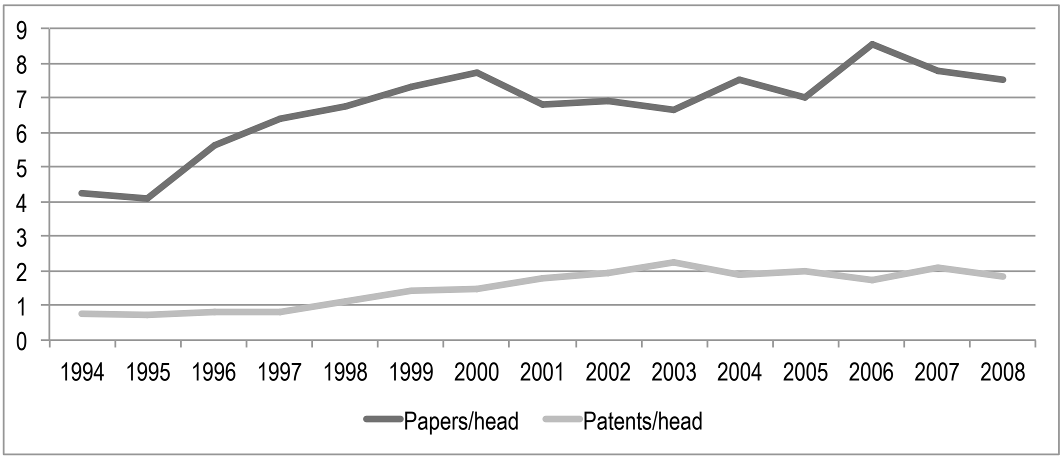

Figure 2.5: Papers and patents per faculty

Third, in comparison to other studies of similar scope (Agrawal and Henderson 2002; Czarnitzki, et al. 2009; Fabrizio and Di Minin 2008; Goldfarb and Marschke 2006) our sample exhibits a very high average number of publications and patents. For patents, they are above any study we are aware of. This reveals one of the major benefits, and drawbacks, of this study: we are in presence of a very high technologically inclined sample of individuals. It is therefore very interesting to analyze the behavior of such a population, as they might combine academic and technological parts of their work. The problem with this is that results might not be easily generalized.

Figures 2.6 presents a histogram of the total number of both patents and publications. Both distributions are heavily skewed to the left, even though for publication data the histogram is more flat. These results are in line with general results of scientific productivity: very few scientists are producing the bulk of the writings, while a silent majority uncloaks very low levels of outputs.

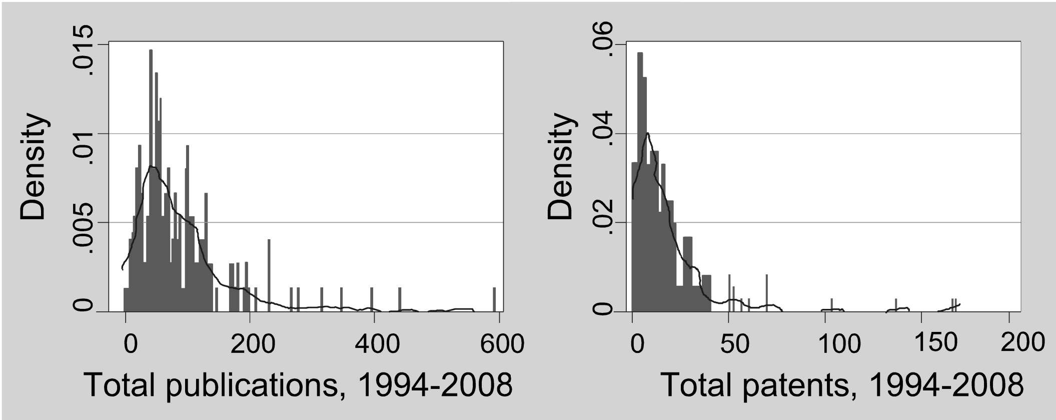

Figure 2.6: Publication and patent frequency

Table 2.9: Correlation matrix

	Paper	Paper (t-1)	Paper t-2)	Paper (t-3)	Patent	Patent (t-1)	Patent (t-2)	Patent (t-3)	Grant	Grant (t-1)	Grant (t-2)	Grant (t-3)
Paper	1.0000											
Paper(t-1)	0.7597	1.0000										
Paper(t-2)	0.7016	0.7607	1.0000									
Paper(t-3)	0.6278	0.6994	0.7609	1.0000								
Patent	0.1767	0.1618	0.1615	0.1774	1.0000							
Patent(t-1)	0.1862	0.1727	0.1650	0.1663	0.8689	1.0000						
Patent(t-2)	0.1706	0.1799	0.1657	0.1617	0.8519	0.8704	1.0000					
Patent(t-3)	0.1692	0.1652	0.1738	0.1663	0.8231	0.8552	0.8702	1.0000				
Grant	0.1567	0.1544	0.1476	0.1218	0.1807	0.1795	0.1937	0.2121	1.0000			
Grant(t-1)	0.1362	0.1719	0.1713	0.1534	0.1990	0.2141	0.2014	0.2160	0.5455	1.0000		
Grant(t-2)	0.1324	0.1480	0.1859	0.1721	0.2291	0.2166	0.2229	0.2062	0.3019	0.5390	1.0000	
Grant(t-3)	0.1417	0.1445	0.1635	0.1859	0.1979	0.2087	0.1966	0.2071	0.2100	0.3413	0.5643	1.0000

Table 2.9 shows correlation coefficients for a variety of flow measures of patenting, publications and grants. There is a clear correlation between patenting and publication over time. This is less the case for the grants. In the same vein, the table gives evidences that patenting and publishing behaviors are correlated with each other, with all the correlation coefficients in the range of 0.16 to 0.18.

We observe that the highest correlations are for $paper_{(t)}$ with $patent_{(t-1)}$, $paper_{(t-1)}$ with $patent_{(t-2)}$, and $paper_{(t-2)}$ with $patent_{(t-3)}$. This relation calls for some clarification on the timing of patent application and paper publication. Our patent variable is recorded by application year. However, publications are not observed according to the date of submission of the manuscript – this information is not available – but according to publication date. This is one of the problems in measuring the dimension of time between these two variables. Indeed, the time between submission and publication of an article varies extensively according to disciplines, from a few months in physics to a few years in economics and management. So what does this tell us about the previously mentioned coefficients? In order to meet legal requirements, patent application has to be solicited before publication of research results. Even if the academic exception can be pled, it is the normal timing. This procedure is explained in the university internal documents aimed at facilitating patent application. Therefore, the submission date of a paper should be occurring later than patent application, the relation between a paper published in time t and a patent application in time t-1 is likely to measure events that occurred the same year. In other terms, we assume that a one-year time difference between the filing of a patent and the publication of an article connects two events that took place at the same time. The high correlation found for $paper_{(t)}$ with $patent_{(t-1)}$, $paper_{(t-1)}$ with $patent_{(t-2)}$, and $paper_{(t-2)}$ with $patent_{(t-3)}$ is a sign pointing toward the co-occurrence of events (Callaert, et al. 2009). In other words, patents and publications might be in some cases by-products of some common research (Murray 2002).

c. *Empirical analysis and results*

- Publication-patent relationship: flow measures:

To investigate the publication-patent relationship we employ fixed-effects Poisson models as introduced by Hausman et al. (1984). As the basic Poisson model assumes equidispersion, i.e. the equality of the conditional mean and the variance, scholars have used negative binomial regression models in the past decades, as these allow for overdispersion, which is typically present in microdata. Overdispersion refers to the fact that the variance is larger than the conditional mean. However, Wooldridge (1999) has shown that the Poisson model is consistent in spite of over-dispersion. In that case, standard errors are biased and thus have to be corrected, which amounts to the calculation of fully robust standard errors.

We employed the following model with publications as the dependent variable, incorporating unobserved heterogeneity through a fixed-effect model. Our specification looks as follows:

$$E(y_{it}|x_{it}, \alpha_i) = \alpha_i exp(x'_{it}\beta) \tag{2.5}$$

where α_i denotes the individual-specific effect. The α_i are random variables that capture unobserved heterogeneity. The key assumption here is that the unobservable α_i are time-invariant, rather than being of a more general form α_{it}. This denotes the unobserved ability of a researcher that might be caused by factors such as better education, creativity, intelligence, higher ambition or even luck. The use of fixed effects specifications is often favored in studies using microeconomic data. However this comes at a cost: time-constant variables cannot be included in a fixed-effects model. As a result, individual specific attributes of the researchers, such as status, gender and field of expertise, cannot be included. In order to test the rightfulness of the fixed effects specification we have run a series of Hausman tests of random versus fixed effects. They reject the random effects model in favor of the fixed effects model.

We estimate Equation 5 using a conditional fixed effects Poisson quasi-maximum likelihood estimation. This functional form is quite flexible, allowing for correlation in the variance co-variance matrix to adjust the standard errors to the possibility of correlation across observation a given individual. Gourieroux et al. (1984) have shown that because the Poisson model is in the linear exponential class, its coefficient estimates are consistent if the mean is correctly specified (the robust standard errors are consistent even under misspecification of the distribution). We therefore report robust standard errors. However, it is possible to improve efficiency by making more restrictive assumptions on the way the variance differs from the mean, which is why we also report results of negative binomial regressions.[29] We have decided to address the endogeneity problem common to such analyses by using fixed effect model. Another method would have been to consider patenting as a treatment effect (Frabrizio and Di Minin 2008; Azoulay et al. 2006 ; Buensdorf 2009). In that way it is possible to test whether the advantage of academic inventors (the treated group) over their colleagues (the control group)

[29] All regressions using the conditional fixed effects Poisson quasi-maximum likelihood estimation were performed in STATA using the user-command *xtpqml* written by Tim Simcoe.

increases after applying for a patent. Despite of the advantage of such a treatment, we were not able to implement it, as we could not create a control group of researchers. Not having information on researchers concerning their professional address over a long period, we could not create a control group due to the fact that we could not retrieve patent data without an address.

Table 2.10: Fixed effects models: Publication as a function of patenting activity and grant numbers

	QMLE Poisson 1 (a)	Negative Binomial 1 (b)	QMLE Poisson 2 (a)	Negative Binomial 2 (b)
Patent(t-1)	0.021***	0.017**	0.017***	0.014*
	(0.005)	(0.006)	(0.004)	(0.006)
Patent(t-2)			0.007○	0.005
			(0.004)	(0.005)
Patent(t-3)			0.016**	0.013*
			(0.006)	(0.006)
Grant	0.004**	0.005***	0.005**	0.005***
	(0.002)	(0.001)	(0.002)	(0.001)
Grant(t-1)			-0.000	-0.000
			(0.002)	(0.002)
Grant(t-2)			-0.002	-0.002
			(0.002)	(0.002)
Grant(t-3)			0.001	0.001
			(0.003)	(0.004)
Promotion	-0.017	-0.017	-0.032	-0.031
	(0.054)	(0.048)	(0.053)	(0.048)
Age	0.135***	0.136***	0.079○	0.085*
	(0.028)	(0.026)	(0.040)	(0.035)
Age^2	-0.001***	-0.001***	-0.001*	-0.001*
	(0.000)	(0.000)	(0.000)	(0.000)
Constant		-1.696**		-0.031
		(0.590)		(0.785)
Observations	2492	2492	2136	2136
Log Likelihood	-6049.151	-5643.005	-4994.099	-4742.493

Notes: (1) Dependent variable is the count of the number of papers in year t
(2) Robust standars erros, cluster by individuals, in parentheses
(3) ○Significant at 10%, * Significant at 5%, ** significant at 1%, *** significant at 0,1%.

The results show that patenting increases publication quantity in all our specifications (Table 2.10). In specification 1, we regress a count of publication on a count of patent. The coefficients are positive and highly significant. In other words, the number of papers published in *time t* appears to be correlated to patents applied in *time (t-1)*. This provides an argument to the idea that patents and papers are two channels used simultaneously to communicate the results of an ongoing research agenda. Patents are most often the by-product of a fertile research project. Our results are in line with results found for the Italian case (Breschi, et al. 2005), for the French case (Carayol 2007), and in the American setting (Azoulay 2006).

Next, we add lagged patent measures in model 2. The $patent_{(t-1)}$ variable is still significant, although with a slightly smaller coefficient. An important finding is that the number of patents applied for three years ago is related to the number of papers written today. Usually, it takes between 18 to 24 months from a patent application to its publication. Hence, there is a kind of sequential relation between patenting and scientific performance. The fact that patents written three years ago affect todays publications alludes to a positive impact of patent publication on current research. When a patent is published and shared with a wider community, it may entail new scientific opportunities. Perhaps more saliently, prior to the patent grant date, the patent applicant holds no formal IPR, and, in nearly all cases, cannot sue for infringement of activities undertaken during the pre-patent grant period. Murray and Stern (2007), studying the impact of patenting on follow-on research, suggest that a patent grant could be considered as "news" or a "surprise" to the research community. In that sense, a researcher may, intently or not, delay some line of research until a patent is granted, and thereafter engage some further research related to the patent.

Regarding the financial variable *Grant*, it appears to lead to higher publication outputs. In model 2 we add a lagged measure of the variable *Grant*. None of the related coefficients are significant. This makes sense, as we have data on a yearly basis. According to Grant-in-Aid for Scientific Research guidelines, all the amounts received have to be used within a fiscal year, except in some cases where the funds can run for the next fiscal year. As such we can argue that funding is directly channeled in work that results in immediate publication.

The age of the scientist is positively linked to the research productivity in all our specifications. The number of publications per year increases with the age of the scientist, but at a decreasing rate over time. This is in line with the finding of Levin and Stephan (1991) with respect to the publication life cycle of academic researchers. The dummy variable *Promotion*, the fact that a researcher was promoted during our period of inquiry, does not affect the publication output in our model.

- Cumulative effect:

We now try to model the effect of patent stocks. We are no longer comparing a single year's patenting output with a single year's publishing output. Indeed, we use stock rather than flow measures. We compute a depreciated stock of patents and publications using a perpetual inventory model. Through the impact of the depreciation rate δ, Equation 6 captures the fact that the recent output of a scientist's research should influence current behavior more strongly than past research:

$$STOCK\_Output_{i,t} = (1-\delta)STOCK\_Output_{i,t\text{-}1} + FLOW\_Output_{i,t} \tag{2.6}$$

We used a depreciation rate of 20%, which is common in this kind of analysis (Henderson and Cockburn 1994). Results of the analysis are shown in Table 2.11. We used a simple regression setting, as the data are not composed of count data. We regressed the depreciated stock of $paper_{(t)}$ over the depreciated stock of $patent_{(t-1)}$ and its squared value.

The results of the regression show a positive and significant coefficient of the linear term, together with a small squared term, negative and significant. This result hints toward an inverted-U relationship between the cumulative number of patents of a researcher and its number of publications. As we have shown before the two activities are complementary. However, these results indicate the existence of a curvilinear relationship. After some thresholds the relation starts to be negative. There might be a time constraint phenomenon in place, in such a way that both activities might be undertaken at the expense of the other. There might also be a shift in the research agenda, with scientists focusing more on patentable research projects, to the detriment of more publishable research. Our results are at odds with Agrawal and Henderson's (2002) findings in their case study of MIT and with Fabrizio and Di Minin (2008) findings in the American case. We deal with this question in more details in Chapter 4.

- Reverse relationship

Table 2.11: Regression of stock levels

		Depreciated stock of paper (t)
Depreciated stock of patent(t-1)		1.162**
		(0.412)
Depreciated stock of patent(t-1)^2		-0.003*
		(0.001)
Age		2.541***
		(0.243)
Constant		-101.567***
		(10.286)
N		2492
R2	—Within	0.6127
	—Between	0.0684
	—Overall	0.2357

We now test the reverse relationship and estimate the effect of paper outputs on patents. The results are very similar, but show some interesting differences (Table 2.12). Papers and patents are positively correlated: while the lagged variable $paper_{(t-3)}$ positively influences patent output in both specifications, it is significant in only the negative binomial model. The coefficient of the lagged variable $paper_{(t-2)}$ is contrastingly negative. This result is surprising: we do not have any convincing explanation to this phenomenon.

We ran regressions including the grants and its lagged values, but none of the relative coefficient was of any statistical significance.[30] We therefore used the number of grants that a scientist was managing in a given year. The intuition behind this was that the important factor might not be the amount of money received, but rather the number of opportunities that multiple projects could generate. The results confirm this intuition: the number of grants in year (t) and (t-2) have a positive impact on the dependent variable. The number of grants in year (t-3) is slightly significant (at the 10 percent level) in the Negative Binomial model. The dummy variable, *promotion*, is positive in both models, but only significant in the

[30] In order to not overwhelm the manuscript we do not report the results, they are, however, available on request.

Negative Binomial model. People who have been promoted patent more than the one's who have not. Being promoted gives more freedom to an academic to pursue his or her research, and therefore could lead to more patenting activities. In parallel, patents increase at a decreasing rate with age. This result is in contrast with the one we found for the cross-section analysis. The reason for this may lie in the timeframe difference. In the cross-section, we focus on a post-reform sample, where many young researchers have started to patent, responding to policy incentives toward a pro-IP attitude, therefore biasing results in favor of the younger cohort. In the panel setting, we have a sample of experimented researchers who have all patented their discoveries at least once: their decision to do so preceded policy changes. In that regard, the decision to patent increases with age, as it has been found in other studies. Older scientists have more opportunities and are freer from academic career criteria to engage in IP activities.

Finally, we estimate the determinant of faculty patenting behavior. We create a dummy variable, *Patent event*, taking the value one if a researcher invented at least one patent for a given year, and zero otherwise. In doing so, we estimate what influences a scientist's propensity to patent. We do so by estimating a fixed-effect logit model. By using the variable Patent event, we treat patenting as a repeatable event. The results presented in Table 2.12 show that the number of $paper_{(t)}$ and the number of $paper_{(t-3)}$ increase the probability to encounter a patenting event in a given year. The other variables do not seem to influence the probability to patent.

d. *Summary of the main findings*

The main added-value of this section, in comparison to the previous one, is to have introduced a dynamic of temporality. We found simultaneity in the publication of research results through patent and publication. Publications published in *time t* are correlated to patents applied in *time (t-1)*. This supports the idea that patent and papers are two channels used simultaneously to communicate the results of an ongoing research agenda, an element we will develop further in Chapter 5. Additionally, we found that patents applied for in *year t-3* were positively correlated to publication in *time t*. This result can be interpreted in the following

Table 2.12: Regressions with patents as the dependent variable

	QMLE Poisson	Negative Binomial	Logit
	Patent	Patent	Patent event
Paper	0.012*	0.012+	0.032*
	(0.005)	(0.007)	(0.016)
Paper(t-1)	-0.007	0.000	0.008
	(0.004)	(0.005)	(0.015)
Paper(t-2)	-0.012**	-0.011+	-0.022
	(0.004)	(0.005)	(0.016)
Paper(t-3)	0.008	0.019***	0.050**
	(0.007)	(0.005)	(0.015)
Grant Count	0.085*	0.063	-0.041
	(0.039)	(0.042)	(0.084)
Grant Count(t-1)	0.008	0.029	-0.031
	(0.034)	(0.041)	(0.088)
Grant Count(t-2)	0.066*	0.075*	-0.014
	(0.027)	(0.032)	(0.088)
Grant Count(t-3)	0.031	0.069+	0.017
	(0.031)	(0.041)	(0.081)
Promotion	0.256	0.231*	0.159
	(0.159)	(0.092)	(0.241)
Age	0.294***	0.265***	0.160
	(0.083)	(0.079)	(0.120)
Age^2	-0.002**	-0.002*	-0.002
	(0.001)	(0.001)	(0.001)
Constant		-7.340***	
		(1.738)	
Observations	2100.000	2100.000	1992.000
Log Likelihood	-2589.6627	-2358.6776	-714.309

Note: Patent event is a dummy variable taking the value 1 if at least one patent was applied by a researcher for in a given year.

way: the publication of patent documents has a positive effect on the publication activity. While a patent is under revision, the information of the document is restricted to the applicant, but, when it is published (usually after a period of around 2 years), the document becomes publicly available, creating new opportunities for publications. On the other side of the relation, papers published in *time t-3* positively influenced the patenting activity in *time t*, indicating the influence of past research projects in the production of patentable research results. These results clearly indicate a sequential relation between patenting and publications activities.

On top of that, using stock measure instead of flow measure, our results reveal an inverted-U relationship between the cumulative number of patents and publications. Generally, the relation between the two variables is positive, but after a threshold, it appears to show diminishing returns. Researchers investing too much time in their technology transfer activities may be less productive in terms of papers produced relatively to their colleagues.

Finally, the number of publications and patents per year increases with the age of the scientist, but at a decreasing rate over time. Researchers who have been promoted during our period of inquiry have a higher patenting activity than their non-promoted peers. In terms of opportunities, we have shown that the number of research grants a scientist manages, and not the amount of these grants, is positively linked to the patent application level.

2.4 Conclusion

We started this chapter by explaining the policy changes that took place in Japan regarding university-industry relations, especially focusing on IP rights. We then moved to two econometrics exercises centered on the case of Tohoku University. Our chief findings can be summarized in three points. First, we have documented the policy-push directed toward an intensification of university-industry relationships that occurred recently. As a result, the number of patents and contractual research agreements have increased rapidly. However, this increase did not originate from scratch. Particularly, before the Incorporation of national universities the majority of IP rights were transferred informally to industrial partners, this practice has changed nowadays as universities are managing a larger share of the IPs originating within their walls. This increasing use of formal IP rights made vivid the needs for an answer to the following question: What is the influence of patenting, which we use as a proxy for academic enterprises, on publishing activities? The answer to this question was at the core of our econometric exercises. This leads us to our second set of results.

We found that patenting and publishing were complementary in our two empirical settings, first, within a large dataset comprising the majority of the faculty members of the engineering and science departments, and second, in a smaller sample of commercially-inclined scientists. In both cases, the two activities showed signs of complementarities, although in one of our models, using stock rather than flow measures, we found a nonlinear relationship between these two variables, the two activities reinforcing each other until a certain threshold and thereafter going in the opposite direction. Another interesting result concerns the influence of a researcher's age on his/her propensity to patent. In our panel data framework, as one would expect from results in similar studies, the number of patent per year increases with the researcher's age, but at a decreasing rate over time. Contrastingly, in our snapshot of the post Incorporation era, the tendency is reversed, the youngest cohort of researchers, between 25 and 35 years old, is the most active in patenting their results. This may indicate the influence of policy changes: the younger researchers are more prone to embrace patenting as one element of their daily research, because their social environment publicizes the activity as a routine activity that is part of their duties. We shall reconsider this element in the next chapter, unveiling the results of a survey centered on the motivations behind academic patenting.

A third accomplishment of this chapter is highlighting the importance and influences of contractual funding and research grants on patenting and publishing. Looking for funds is an important factor of academic life that in turn affects the way faculty conduct their research. It is worth noting here that this is not a new phenomenon:

> [T]he free university, historically the fountainhead of free ideas and scientific discovery, has experienced a revolution in the conduct of research. Partly because of huge costs involved, a government contract becomes virtually a substitute for intellectual curiosity. For every old blackboard there are now hundreds of new electronic computers. (Eisenhower, 1961)

This quotation, taken from Dwight Eisenhower's farewell address, expresses, albeit a bit dramatically, the almighty influence of funding on the research agenda. In a more humble way, we would like to stress the importance of contractual research regarding Japanese universities' technology transfer. In the case of Tohoku University, we documented the fact that a high proportion of patent filing is formally linked to contractual research documents. It therefore seemed logical to test their influence on the patenting activity in a more analytical way.

The results show that contractual research and patenting go hand-in-hand. The amount of funds received by a researcher is positively correlated with his/her number of patents. Having worked with an industrial partner increases a researcher's propensity to patent. As for funds received from research grants, they increase the level of publication outputs, but are not correlated with the level of patenting. Nevertheless, we did find a positive relation between the number of grants – not the amount – a scientist manages in a given year and his patenting output. Our educated guess on the matter is that research grants are mainly channeled toward traditional goals of academic research, the main desirable outcome being publications. This process is self-reinforcing: the more publications you have, the more people are willing to provide you funding. This phenomenon is known as the famous Matthew effect. Furthermore, if a scientist is engaged in many research trails, commercial opportunities are more prone to appear, as the potential commercial uses of scientific discoveries multiply. Our results give supporting evidence to this idea.

The results in this chapter have demonstrated the need to consider the financial aspect of the picture. In our view, this element has to be included in any further study, when available. The use of patent documents and their citations, as well as the use of publications, their citations and relative impacts provide some valuable information on the output side of the story. More and more refined techniques are used to take advantage of this data. For instance, Rosell and Agrawal (2009) compared university-to-firm patent citations across two time periods to show that the university diffusion premium – the fact that university knowledge is more widely distributed than knowledge of firms – declined in recent years. Despite these useful refinements, we believe that there is a need to enrich the input side of the story to study how different sources of funding shape the rate and direction of innovative activity.

From this chapter's findings, we begin to realize that university-industry relationships and the norms and practices attached to it are influencing the way university scientists do research. University and industry practices are becoming more alike. We can here mention the idea of isomorphism. In the 1990's, Hackett (1990) developed this idea when arguing that changes in external relations of universities would affect their internal practices in the future. Greater dependence on the private sector for resources could lead universities to increasingly resemble the private sector. And indeed, this chapter made clear that a push toward a greater use of IP rights by academics is on its way. Industrial norms and values are infiltrating the university through funding, contacts with corporate partners and the use of patents.

We shall refrain from referring "capitalization of knowledge" by academic researchers, as heralded by Etzkowitz et al. (1998), wherein commercial interests subdue intellectual curiosity. So far, it is too early to be definite on that matter, but our quantitative evidence push toward a picture where the two activities, commercial and academic, patent and publication, cohabit peacefully. One possible explanation for empirical complementarities established by our study and many others are to be found in the concept of co-occurrence of many research results (more on this element in Chapter 5). Fiona Murray and her collaborators in a series of works on biotechnology related fields found that many research results are both patented and published (Murray 2002; Murray and Stern 2007; Murray and Stern 2008). An engineering faculty member interviewed by Agrawal and Henderson (2002, p. 58) stated "most patentable research is also publishable." One reason for this duality is the high prevalence of research that is both use-oriented and also oriented towards fundamental understanding – what Donald Stokes calls Pasteur's Quadrant. We will come back to this element in Chapter 4. Our results are however bounded by their quantitative aspects that unable us to gain a better understanding of why researchers engage in these relatively new activities for academics, namely the commercialization of their discovery.

In the next two chapters, we move to qualitative evidence to investigate the influence that industrial science and technology transfer considerations have on university science, and therefore aim to gain a better understanding of the phenomena at stake in university-industry relations. In this chapter, we investigated *what* the relations are between academic and commercial missions of a scientist. We shall now try to understand *how* faculty members perceived the impact of patenting and industrial contracts on their research agenda, and *why* they engage in such activities. These questions call for qualitative evidence. Responses to a survey of academic patentees are presented and analyzed in Chapter 3. In Chapter 4, we report insights gained from interviews with ten prolific researchers in the field of material science, which is a field of excellence at Tohoku University.

CHAPTER 3

WHO IS PATENTING IN ACADEMIA, FOR WHICH REASONS, AND WHAT ARE THE PERCEIVED IMPLICATIONS? SURVEY ANSWERS

If one does not know whether a system "as a whole" (in contrast to certain features of it) is good or bad, the safest "policy conclusion" is to "muddle through" - either with it, if one has long lived with it, or without it, if one has lived without it. If we did not have a patent system, it would be irresponsible, on the basis of our present knowledge of its economic consequences, to recommend instituting one. But since we have had a patent system for a long time, it would be irresponsible, on the basis of our present knowledge, to recommend abolishing it.

— Machulp (1958)

3.1 Introduction

Long gone are the days when “all” academic scientists could embark on disinterested research projects and free themselves from intellectual property (IP) considerations. What a young Marie Curie would do today is subject to interrogation. As a young scientist, she serendipitously discovered radium and polonium in the course of her doctoral research. Her position on commercializing the discovery was clear. She argued in a discussion with her husband about patenting their invention of radium that "Physicists always publish their research completely, if our discovery has any commercial future, that is an incident by which we must not profit. And radium is going to be of use in treating patients... It seems to me impossible to take advantage of that." (Curie and Sheean 1938, p. 204). Indeed, the potential of such discoveries were going to become major components of medical research, however, she did not patent any processing methods or potential medical applications, but rather freely gave away radium for cancer treatments and openly shared information about its fabrication process. Recent developments in life sciences call for another story where IP rights take an central place (e.g. Murray, 2009). Although Curie refused to patent her discoveries, she later worked with industrialists to finance her research: Andrew Carnegie provided financial support to her laboratory from 1907 onward, and several other commercial companies interested in radium purification technologies provided her with targeted funding (Macklis, 2002).[1] This story has been portrayed here, as it is reminiscent of some elements we found in the survey we conducted: a certain vision of academic freedom and an inclination toward industrial collaborations.

We stressed in previous chapters that academic patenting gained momentum in recent years. We do not know if these changes are good or bad, such a judgment would be too categorical anyway, but as Fritz Machlup (1958) observed long ago, in summing up his review of the economics of the patent system, because of its complexity and our imperfect knowledge of the system, the only solution is to "muddle through" it. Therefore, to improve our understanding of that system, which gradually permeated through academia, we believe that one can gain valuable insights of this trend and its influence by directly asking academics their opinion on the matter. Empirical studies using the academic inventor's point of view are still scarce, scattered and fragmented, hence we believe that we could add some valuable insights by conducting such an inquiry.

As a result, the aim of this chapter is to gain a better understanding of the motivation behind the act of patenting in academia, to measure the perceived consequences, and evaluate the influence it exerts on academic researchers. Our questions are of the order of "who" and "what", while being explorative as it should

[1] Curie's industrial activities were an integral part of her research effort. It enabled her to search new problems, to develop instruments, improve extraction techniques of minerals, and so on. (Roqué, 2001)

help us to better grasp the motivation of researchers. Thus, following Yin's (1994) recommendations, we decided to use a survey method. This method has the advantage of being quite flexible, enabling us to design questions that would complement our work in the previous chapters, and to bring our understanding of how academics function in a changing environment one step further. Logistically speaking, we sent a survey to all the faculty members who have been listed on a patent at Tohoku University from 2004 to 2009. In Japan, as we have shown in Chapter 2, the impetus for stronger use by academia of IPR was prevalent in recent years, indeed a set of legislation was voted to favor university-industry relations (UIR) and ease patenting, leading to sharp increase in university patents. It is therefore appealing to poll researchers in a university like Tohoku which has embraced policy changes with vigor. Table 3.1 provides an order of magnitude of the scale of the phenomenon and presents the number of patents and publications produced by the university since 2004.[2] Based on Table 3.1 we note that the average paper-to-patent ratio is around 10; to benchmark the results this value is of the same magnitude as the results found for MIT by Agrawal and Henderson (2002), an institution renowned for its entrepreneurial activities and its high patenting level. Although these numbers are high they show that patenting is a minority output in the academic game. Our aim is to analyze how such an activity affects the practice of scientists.

Table 3.1: Patent, publication and ratio

	2004	2005	2006	2007	2008
Patent application	306	414	405	389	357
Paper	3502	3759	4354	4342	4413
patent/paper	11.44	9.79	10.75	11.16	12.35

Source: The number of papers was retrieved using the Scopus online database by looking at papers containing at least one Tohoku University's affiliation. The numbers of patents were found using documents for the university's IP Office.

This chapter is organized as follows. Section 3.2 summarizes selected contributions that have been published regarding researchers' perception of commercialization and patenting in academia. Section 3.3 describes the data and is more

[2] The search was done on http://www.scopus.com the 01/05/2010.

precise in defining the goal and scope of the survey. Section 3.4 presents the main results of the survey: stressing the motivations, consequences, and the influence on researchers' agenda to be involved in the patenting process. Finally, in Section 3.5, we analyze more thoroughly the influence that patenting has on the direction and dissemination of research results.

3.2 Commercialization and patenting

In this section we review some selected empirical studies, which use a similar approach to ours and try to detect some regularities in their contents. This section moves in concentric circles, from the large picture of motivations to engage with industry, to its perceived influence and finally to the narrower subject of academic patenting. The glue between these levels is the methods used, survey and interview, to probe into the arcane of the academics' minds. Our goal here is to see what constitutes consensus and what is still to explore in the literature to construct and exploit our survey.

3.2.1 Reasons to cooperate with industry

Academic patenting is an output of commercialization activities. What we want to see here first is, why such commercialization activities occur, and more generally why an academic may want to engage with industry. In investigating the reasons behind cooperating with industry, the contribution of Lee (1996) is a pioneering one. Based on survey data of 986 faculty of US universities, he found that the strategy orientation towards applications and/or commercialization of research results depended on the type of faculty's scientific field (engineering and applied science or basic sciences), the university's overall policy of encouraging transfer activities, the "research-dollar connection", and the perceived positive or negative impacts on traditional university missions. In a nutshell, (1) applied science faculty are among the strongest supporters of technology transfer activities; (2) universities where industrial contacts are encouraged see faculty to be more favorably disposed to the various transfer mechanisms; (3) extra research dollars enable the research outputs and are influencing the perception of transfer activities: the more cash constrained a scientist is, the more he/she is likely to be lenient toward industry; (4) and finally, faculty support towards UIR is strongly affected by how they perceive their likely impact on academic freedom, long-term research orientation, and academic integrity, a negative perception on any one of these issues will undermine their support to UIR. Generally, Lee points out that "faculty members seem quite certain that a close collaboration between university and industry is likely to increase pressure for short-term research thereby affecting long-term basic research. While the opinions are divided on the question of academic freedom, faculty are less certain of its consequences on conflict of interest." (Lee 1996, p. 857).

In a subsequent study, based on 671 faculty scientists and engineers from 40 US universities, Lee (2000) goes a step further in trying to evaluate UIR by focusing on their "behavioral outcomes", in particular on what faculty get out of their collaboration. Table 3.2 summarizes the underlying motivations of university faculty and firms when collaborating on R&D projects. The most important motivations in the view of scientists are to secure additional funds to do research, buy equipment and foster one's own research agenda. Looking for business opportunities ranks last and therefore does not seem to be a pivotal factor. UIR are rather seen as a way to boost research.

Table 3.2: Ranking by faculty members of UIR outcomes

Outcomes of UIR: Faculty view	Ranking
Secure funds for graduate assistants and lab equipment	1
Gain insight into one's own research	2
Field-test application of one's own theory	3
Supplement funds for one's own research	4
Assist university's outreach mission	5
Create student jobs and internships	6
Gain knowledge useful for teaching	7
Look for business opportunity	8

Source: Adapted from Lee (2000)

Welsh et al. (2008), using the results of 84 interviews with biological scientists, find that scientists view UIR with dual lenses. Their results suggest that, on one hand, UIR are valuable to increase interactions with industrial scientists, facilitating access to new knowledge, and providing additional research funds. On the other hand, they are a source of tension as they may generate conflict of interest and communication restrictions. The interesting point of Welsh's study is that scientists are aware of the pros and cons of UIR, and that the challenge lies in the way they are balanced. In the same direction, Lam (2010), based on 36 interviews and a survey of 734 academic scientists from five UK research universities, describes a complex picture of scientists' attitudes towards industry. Using Gieryn's (1983) concept of 'boundary work', the propensity of scientists to draw and redraw the boundaries of their work to defend their autonomy and secure resources, Lam shows that academic scientists manage to find a degree of control over their science–business relationships in order to pursue their own objectives, within a "strong scientific ethos that cherishes autonomy and dedication to knowledge" (Lam 2010, p. 334). There are tensions originating from collaborations with industry, but scientists try to overcome them to push for their agenda. As a conclusion, academics who are involved in UIR cannot avoid ambivalence. They navigate between Scylla and Charybdis; results of the surveys and interviews tell a story of needed industrial partners for funds and research projects, while trying to avoid potential encroaching of the scientific ethos.

3.2.2 Channels of cooperation

Now that we are more aware of the motivations and apprehensions behind UIR, the next step is to investigate the various channels of cooperation. Based on a large scale survey of UK university researchers, D'Este and Patel (2007) empirically describe five broad categories of interaction with the industry: *creation of new physical facilities, consultancy and contract research, joint research, training* , and *meeting and conferences*. Moreover, they found that these five categories were only weakly correlated, indicating that these activities are largely non-overlapping: researchers often specialized in one of the above-mentioned activities only. In line with the results of Lee (1996), D'Este and Patel find that the proportion of researchers involved in interactions with industry varies across scientific disciplines. There is, for instance, a high level of interaction within engineering disciplines relative to physics and mathematics.

Additionally, D'Este and Patel's results show that individual characteristics of the researcher have a stronger impact on their collaborative inclination than the departmental or university ones. First, previous collaborations with industry are a determining factor in engaging in new collaborations: there is a cumulative effect. On this subject, a sister study by Bruneel et al. (2010) elaborates on this issue and shows that trust building is an important factor in the realization of successful partnerships between university and industry. Indeed, it requires long-term investment to bridge the gap between the two ethos of doing science. With time, a mutual understanding about the different incentive systems and goals can emerge and lead to sustainable successful relationships. Second, academic status, such as professor ranking, has a positive impact on the frequency, as well as on the variety, of interactions with industry. Professors are more involved in UIR than their lower ranked colleagues. Finally, all things being equal, younger researchers engage more intensively in a broader range of interactions. On this last point, they hypothesize that "interaction with industry is perceived as positively contributing to the scientist's reputation, encouraging researchers to actively engage with industry in the earlier stages of their careers" (ibid., p. 1309). This result is in line with elements we found in Chapter 2, in the case of academic patenting at Tohoku University, younger researchers looked as if they embraced and balanced collaborations with industry with their academic missions more effectively than their older peers. A similar results can be found in Bercovitz and Feldman (2008): using quantitative methods, they illustrate that the longer time has elapsed since graduate training, the less likely individuals were to actively embrace the commercialization norm. It is not only age that matters, but rather, early exposure to different practices.

In addition to the five above-mentioned ways of collaborating with industry, authors talk about informal technology transfer, even if no clear definition of the terms emerge yet. In order to define this concept, Link et al. (2007) refer to informal technology transfer as a mechanism facilitating the flow of technology knowledge through informal communication processes which may involve technical assistance, consulting or collaborative research. The authors draw a line between formal and informal mechanisms by looking at how property rights are allocated: "Formal technology transfer is focused on allocation of property rights and obligations, whereas in informal technology transfer, property rights play a secondary role, if any, and obligations are normative rather than legal." (ibid., p. 642). Using results from a large survey sent to American academics, they investigate this channel. They find that tenured faculty members are more likely than untenured ones to engage in informal technology transfers, their explanation being that tenured faculty members have had a longer time to develop skills and produce bodies of work useful for industry.

Interestingly, they show that faculty members who allocate a relatively higher percentage of their time to grants-related research are more likely to engage in informal commercial knowledge transfer and to publish with industry scientists. In a sister study conducted in Germany, Grimpe and Fier (2009) find relatively similar outcomes. In fact, these results suggest that formal and informal technology transfers may go well together in that informal contacts improve the quality of a formal relationship, or that formal contracts are accompanied by an informal relation of mutual exchange on technology-related aspects. On the other side, looking at how firms cooperate with universities, Grimpe and Hussinger (2008) argue that informal and formal channels are complementary, and that using both transfer channels contributes to higher innovation performance for the firms. These examples illustrate the dual nature of knowledge, tacit and explicit. In order to acquire them both, it is necessary for the collaborating actors to deal with both channels.

We have seen so far what ways academics use to engage with industry, and how these ways are shaped by individual characteristics such as age, scientific disciplines or tenure. We now move to a mainstream indicator of industry involvement: patenting.

3.2.3 University patenting

We now move to examine what survey-based research can tell us about the motivations to patent in academia. As a preliminary precision, we may say that although patenting is not an interaction with industry, it is a signal of the involvment of university researchers towards proprietary knowledge and commercialization activities. A lot of attention has been dedicated to this channel in the literature, yet little is known about the motivations behind such an activity in academia. We present the emerging evidence on such an issue bellow.

Is it for glory or money? Göktepe-Hulten and Mahagaonkar (2010) try to answer this question by looking at the rewards that academics expect from patenting activities which they measure in terms of financial benefits and scientific reputation. They investigate this issue by surveying scientists from the Max Plank Institute in Germany. One of their main findings is that scientists' inventing activities are rather related to their expectations of recognition and reputation while financial benefits are less important. Indeed, they observe that scientists who expect high reputation from commercialization activities are more likely to apply for patents. Their interpretation of this finding is that patenting may act as a signaling device to reach a certain type of audience. On top of that, pecuniary considerations do not seem to affect scientists' propensity to patent. Clearly, reputation-building seems to matter most. This reinforces what we hypothesized in Chapter 1: patenting is not only a mechanism for privatizing information, it is also a means of publicizing discoveries; and the latter matters more in academia. Additionally, Göktepe-Hulten and Mahagaonkar make an interesting distinction between scientists who formally cooperate with industry and the others, and report as a result that the former are not affected by reputational expectations when patenting. Plainly speaking, patenting may increase academic reputation in the industrial sphere, and thus facilitate cooperation, but when a relation is settled, reputation-building is no longer the main motivation. Patenting is rather business as usual for corporate partners. In that sense the patenting outcome of UI collaboration may be of more interest to the firm profit or reputation than to the scientist. In the same vein, Baldini et al. (2007) conducted a survey of Italian academic inventors, which indicates that patenting is seen as enhancing prestige and reputation and providing new impulses for research, but that personal remuneration is not seen as important.

Even if money as such is not a motivation, the reputation and signaling that it entails could generate extra-funding as a consequence. In a study on life scientists in Portugal - some having experience in patenting, some not - Moutinho, et al. (2007) report that around 80% of researchers believe that patenting facilitates collaboration with industry, signals competences and attracts industry funding. These results hint toward patenting as a way to signal its competencies to industry and eventually monetizing through subsequent research collaborations.

Who are the winners and losers? Davis et al. (2009) explore the scientist's perspective on the possible "unintended effects" of university patenting based on a survey of life scientists in Denmark. Their main contribution is to show that basic researchers are significantly more skeptical about the impact of university patenting on academic freedom, while highly productive scientists are significantly less skeptical. They describe the following:

> [T]op scientists, whether they specialized in basic or applied research, were little concerned about the possible effects of university patenting. Applied researchers were also unconcerned. But average or below-average performers who specialized in basic research felt that patenting pressures negatively affected their ability to define their own research agendas (ibid., p. 16).

This result is in line with Thursby and Thursby (2002), who found that faculty who specialize in basic research may choose not to disclose inventions because they are unwilling to spend the time on the more applied R&D that is needed to lure businesses in licensing the invention.

What are, if any, the negative consequences? Finally, we say a few words about the drawbacks of faculty patenting and data-withholding behaviors associated to it. Blumenthal, et al (1997) surveyed 3,394 life science faculty in 50 universities, they describe that 19.8% of the respondents report that publication of their research results had been delayed by more than 6 months at least once by commercial considerations. Of those, 46% reported delays to allow time for patent application. Delays in publication seem to be linked with patenting and commercial considerations, but they also notice that the main reason to deny results and material to colleagues was the struggle for scientific priority. This study caught a lot of attention, so far it has been cited more than two hundred times, in medical and social research.[3] Reasons for this enthusiasm were the following: Blumenthal's study was one of the first large-scale survey on the issue, its results described behaviors not in line with the mores of sciences, and finally it echoed to the increasing commercial pressures faced by scientists in the life sciences. However patenting is not the only reason why scientists do not freely share their research results. Walsh et al. (2005), still in the context of life science, found that patents generally are not used to deny access to knowledge inputs, but that access to others' research material is more difficult. Indeed, none of the scientists they surveyed seemed to care about patents: only 5% (18 out of 379) regularly check for patents on knowledge inputs related to their research. Furthermore, in their study "no one reported abandoning a line of research" because of patents. What seems to be of more importance is that the restricted access to research materials appears, as non-negligible, the main reason behind academics' commercial activities, scientific competition, time and effort required to satisfy requests. Similar results were found by Campbell et al. (2002) in academic genetics. As Walsh et al. remark:

> Our results offer little empirical basis for claims that restricted access to IP is currently impeding biomedical research, but there is evidence that access to material research inputs is restricted more often, and individual research projects can suffer as a consequence. (Walsh et al. 2005, p. 2003)

As a result, patenting looks to be another tool to gain consideration in the competitive academic game. The ones who succeed in it appear to ease their collaborations with industry and obtain additional funding, while the ones who are less lucky or equipped to surf this tendency are more skeptical about it. On top of that, what seems to obtrude into the scientific ethos, at least in life sciences, is rather the denial of material exchange than IP as such.

[3] The Scopus database details 217 citations of the study, 125 in the field of medicine and 86 in social sciences, economics and business studies (search conducted the 18/06/2010).

3.3 Description of the data and the survey

So far our review of the litteraure has identified key features about UIR and IPR usages in academia we intend to build upon. First, the field of research, as well as the age of respondents, seem to shape the vision of academics on such activities. On top of that, access to extra funding and knowledge is one of the major reasons to cooperate with industry, but as such money is not the goal, but rather a way to move forward with one's own research agenda. On the other hand, in interacting with industry and engaging in IPR activities, faculty feel pressed by ambivalent stimuli and face possible constraints on the free and fast diffusion of their knowledge. In our survey we want to address these issues for the case of Tohoku University, which is an institution where academic patenting is actively pursued. Using this case, we want to investigate the type of people who patent (age, tenure, field); second, we want to understand their motivations, and the consequences of patenting on their work; third, we want to see what are the possible drawbacks to patent for faculty members.

3.3.1 The survey

We modeled our questionnaire to take into account our research setting and questions, while at the same time integrating elements of the survey designed by Pénin (2010) who inspected academic patenting in the French context. Many elements of the French survey are integrated in our survey, nevertheless our version is augmented and adapted to tailor it to the Japanese environment and some of its context-specific considerations. This approach has the advantage of allowing us replicability of the experiment, hence providing us with a benchmark to interpret our findings. While using the majority of the questions from French questionnaires, we added some to investigate various specificities of the Japanese context and to address research questions important to us that were not present in the French version. When relevant to our inquiry, we will compare the results of the two surveys, though it is important to remain cautious in comparing them as Pénin's study encompasses all French academic inventors whereas ours is limited to a single case.

Most researchers in our sample are inventors of more than one patent. More than 90% of them report to have been involved in more than one patent. However, for simplicity and to facilitate the treatment of the answers, we were general in framing the questions by not specifically asking for differentiated answers for each single patent an inventor had been dealing with. However, it is likely that there is not one single appropriate answer because each patent application has its own context and story. The figure presented in this chapter must therefore be considered as being an "average" answer; one that in the researcher's mind better fit his experiences. Let us note that more than 60% of our sample has been involved in more than 5 patent applications. For that reason, the story we are portraying here is bound to be the one of researchers who are experienced patentees. This entails the possible shortfalls of an over-optimistic story about patenting as the narrators are actively and repeatedly engaged in the activity. On the other hand, a majority of our respondents have been exposed to IP issues in many circumstances to IP issues, enabling us to tap into their working knowledge and experiences regarding patenting. Being optimistic on the matter, we have preferred a small number of well-informed respondents to a much larger sample of minimally involved subjects.

Finally, as the questionnaire was quite vast, we only present here some of its results – the complete questionnaire can be found in Appendix C. We summarize here the main types of answers we utilize for this chapter, which can be classified in three broad categories. First, we use a series of questions that are aimed at drawing a better picture of who is patenting. Second, we present results on the motivations to patent. Third, we look at both positive and negative consequences of patenting on academic research.

3.3.2 Data

Figure 3.1 depicts the number of full-time faculty members of Tohoku University as of 2008. There were 2,748 permanent members, out of which 810 (29% of the total population) have been involved in technology transfer activity since 2009:

601 (21%) were listed on a patent as an inventor and 606 (21%) were involved in a research contract with industry (commission or collaborative), 397 (14%) were involved in both.

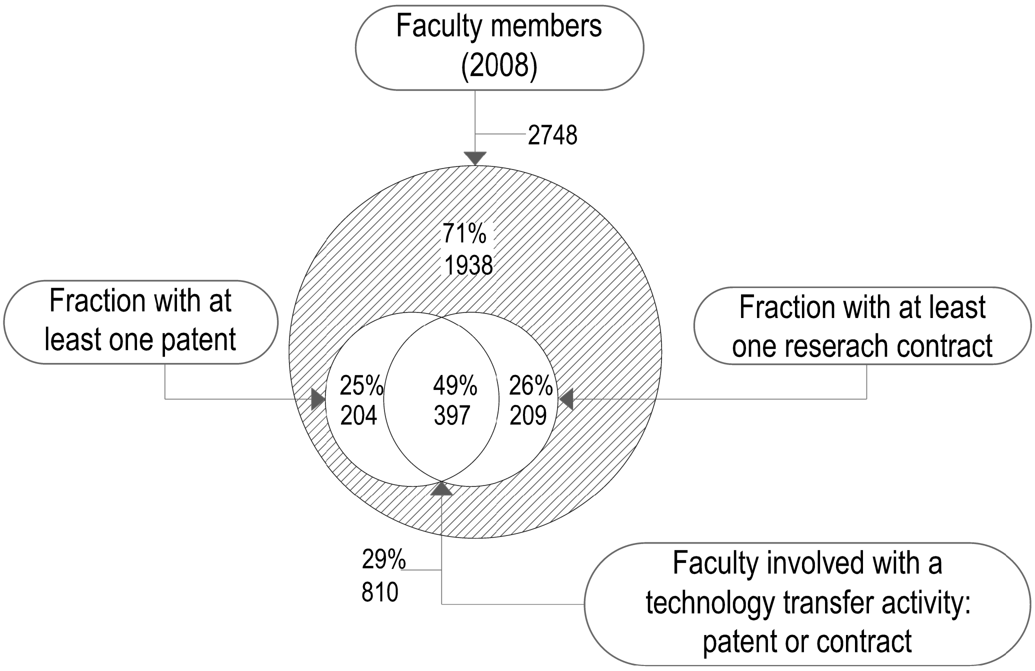

Figure 3.1: Description of the population

Based on the above-mentioned population, this chapter draws on data collected via a questionnaire sent to academic researchers, as part of a survey conducted between April and May 2009. We collected information on 158 academic inventors. By academic inventors we mean faculty members (i.e. assistant, associate and full professors) active at Tohoku University between 2004 to 2009 and mentioned as inventor in at least one patent applied for since 2004. We received data on academic inventors by the IP Office of the university. Under Article 35 of Japan's Patent Law, universities may require their employees to assign work related inventions to the university, all inventions made by university employees have to be declared to the IP Office, it will thereafter decide the strategy regarding patenting. We have retrieved from the Office a list containing all the patent applications by university personnel since the Incorporation of the university (2004). From this list, we were able to identify 667 inventors out of which 601 were full-time faculty members,[4] 17 of the researchers could not be reached. We solicited the researchers by email: an original request was send followed by two remainders two weeks apart. Out of the 584 inventors who received the questionnaire we collected 158 answers, which amounted to a response rate of 27.05%.

Table 3.3: Distribution by gender and academic ranking

	Respondents		Parent Population	
	Number	%	Number	%
Male	151	96%	582	97%
Female	7	4 %	19	3%
Assistant, lecturer	41	26%	201	33%
Associate	40	25%	143	24%
Professor	77	49%	258	43%

Note: based on the complete population.

Tables 3.3 and 3.4 provide the profiles of our respondents according to their gender, academic ranking and scientific disciplines. It also provides similar information for the parent population, which enables us to analyze the representativeness of our sample. Scientific disciplines were coded using the internal research classification adopted by Tohoku University: this system comprises three levels of classification. We selected the first level, the broader one.[5] A quick look at the tables reveal that the distribution of our respondents is quite close to the parent population. Our population is nearly exclusively male, with approximately 50% of them professors, and the most representative field of research being engineering. The high representation of the engineering field lies in the fact that the university has a long and successful research history in the field, that if it is a field of excellence for the university, and it is the largest school within the university.

[4] The rest were mainly composed of post-docs (40), technicians and full-time researchers.

[5] For more details on the classification see http://db.tohoku.ac.jp/whois .

Table 3.4: Distribution by scientific disciplines

Discipline	Respondents		Parent Population	
	Number	%	Number	%
Biological sciences	11	6.96%	36	5.99%
Chemical and physical sciences	36	22.78%	125	20.80%
Medical sciences	26	16.46%	117	19.47%
Pharmaceutical and drugs	6	3.80%	16	2.66%
Engineering	79	50.00%	307	51.25%
Including Materials science	24	15.19%	75	12.48%
———— Electronics	12	7.59%	69	11.48%
Total	158	100%	601	100%

3.4 Findings

3.4.1 Who is patenting?

To begin, we asked the scientists what the main focus of their research was. Answers provided are quite informing (see Table 3.5). First, about one fourth are characterizing their research as rather basic in scope. Another quarter are qualifying their research as both applied and basic, while two-fifths are conducting mainly applied research. Though leading in applied research, there is no clear link emerging between the applied/basic dichotomy and a university scientist's propensity to diffuse his findings through patenting. However, when investigating further attributes of their research projects, the results become clear: 75% of the respondents are working on specific applications whether by the creation of equipment, devices or new materials. Only a small fraction are concentrating their work on the creation of models or simulation methods. What is clear from these results is that it is not the type of research, basic or applied, that seems to be a determinant in the propensity to patent, but rather the specific objectives of the research. A researcher can conduct basic research but in his research might have to design a new material or equipment; in that part of his work he will use patents.

A second interesting insight delivered by the survey lies in the age distribution of the inventors and their perception of patenting (Table 3.6). The reputational based reward system in science tends to produce increasing returns, Merton called

Table 3.5: Research preoccupation and topic

Currently, what is your main research preoccupation?	%
Mainly basic research (rather than concrete problem-solving, your aim is to create new theories and knowledge)	13%
Mainly applied research (developing theories and knowledge with the aim of solving concrete problems)	21%
Rather basic than applied research	14%
Rather applied than basic research	19%
Both basic and applied research	28%
Not aware of the above categories	6%
Please tell us about the features of your current main topic of research:	
Creation of equipments, devices, new materials, instruments, and manufacturing samples	76%
Creation of theoretical models and/or simulations methods	3%
Both of the above categories	18%
Other	3%

Note: Based on 155 responses.

this tendency the Matthew Effect[6] (Merton, 1968; 1988) or the fact that credits and resources are disproportionally attributed to the those who have already been chosen in the past. This concept pays attention to the ways in which initial comparative advantages of trained capacity, publication outputs and available resources make for successive increments of advantage such that the gap between the haves and the have-nots in science widens with time. Consequently, young researchers have very strong incentives to make efforts in the early stages of their career, and if publication is the main channel to judge their work, to concentrate their attention on such an output. Therefore, if patenting is diverting young researchers from publishing articles, and if patenting is not viewed by the community as a signal of research excellence. Young researchers may not consider this activity as a relevant objective and may rather concentrate solely on publication. On the contrary, older researchers may have a higher propensity to patent because their career is already settled and they may benefit from a greater experience and more contacts. Contrary to the belief that patentees are to be found mainly among older academics, which was confirmed by Pénin (2010) in the French context, in the case of Tohoku

[6]The name of the effect finds it origin from a passage of the Gospel according to Matthew (25/29): "For unto everyone that hath shall be given, and he shall have abundance; but from him that hath not shall be taken away even that which he hath."

University, the younger generation of academics (below 40) represents nearly 30% of our population.[7]

Table 3.6: Distribution by academic inventor age

Discipline	French Case (Pénin, 2010)		Tohoku University (Parent Population)	
Age	Number	%	Number	%
More than 65	150	12.2%	32	5.3%
60-64	258	21%	70	11.6%
55-59	183	14.9%	67	11.1%
50-54	148	12.1%	88	14.6%
45-49	183	14.9%	73	12.1%
40-44	205	16.7%	86	14.3%
35-39	90	7.3%	101	16.8%
30-34	11	0.9%	82	13.8%
Total	1228	100%	600	100%

Note: We could not retrieve the age of one researcher for Tohoku University.

These results indicate that, at least in the case of Tohoku University, the younger generation is actively involved in the process, which confirms results depicted in Chapter 2. In an environment favoring patenting, young academics feel more at ease to engage in such an activity. This positive view is confirmed by Table 3.7; indeed 65% of the respondents believe that their patenting activity is seen rather positively by their scientific colleagues, while only 1% (2 out of 154) thinks it projects a negative image. Clearly, among our sample, patenting is rather seen as positive activity, a factor explaining the large proportion of young scientists engaging in such an activity. This phenomenon reminds us of the classical concepts of *latent learning* and *cognitive maps*, which are well-known concepts in the field of psychology. Latent learning is a learning process that is not always demonstrated when it occurs. In our case, an intense immersion in an environment where patenting is widely used exposes young researchers to practices needed to patent, even if they do not use them. In this process, they develop cognitive maps – which are mental representations of a particular arrangement – a way to muddle through settings where patents are used. These cognitive maps are developed naturally though ex-

[7] And even more if we add the post-doc, however as we do not have details on their age, we can only guess that in the large majority they are bellow 40.

perience and can be mobilized swiftly if a scientist wants to engage in the activity. In our case we are guessing that young scientists are forging theses maps by working with colleagues who use IPR constantly, and are responding to institutional pressures to do so.

Table 3.7: Colleagues' perception of academic patenting

How do your scientific colleagues perceive your patenting activity? (Only one possible answer)	%
Rather positive image	65%
Indifference	20%
Rather negative image	1%
I do not know	14%

Note: based on 154 responses.

3.4.2 Motivations to patent: fostering industrial collaborations

The second objective of our survey was to gain a better understanding of the motivations underlying the act of patenting among Tohoku University inventors. We first wanted to evaluate how faculty perceived different channels of knowledge and technology transfer, to see where patenting would rank. To do so, we asked them to rank the different channels of technology transfer depicted in the literature according to their importance. Table 3.8 summarizes the results. A majority of the respondents ranked channels of technology transfer that require direct contacts with a partner highly. Indeed, research collaboration and consulting are cited among the most important channels of technology transfer. However, consulting was seldom chosen as the most important. The subsequent channels are more defined in terms of output as such. First, patenting and licensing score high, perhaps biased as the questionnaire was sent to a population that had prior experience with patents. The second channel is publication. Even though in the academic world, the number of publications is outstandingly superior to the number of patents (see Table 3.1), patent ranks higher as a way to transfer technology. The other factors, such as recruiting or attendance to conference appear to be of comparatively minor importance. What we want to stress from these results is that research collaborations and patents are the two most important channels in transferring technology in our setting. We shall soon see that these two channels are complementary.

Table 3.8: Different channels of technology transfer by university scientists

Rank according to their importance theses different channels of technology transfer:	1^{st}	2^{nd}	3^{rd}	sum of 3 previous columns
Research collaboration	63	29	21	113
Patent and license	40	24	17	81
Publication	11	24	29	64
Consulting	4	27	21	52
Conversation	11	11	15	37
Conference	5	8	15	28
Co-supervision of Thesis	2	8	6	16
Recruiting/hiring	1	4	2	7

Note: based on 153 responses.

Second, we asked our respondents to evaluate different statements regarding potential motivations for filing a patent (Table 3.9). We listed and provided our respondents with the possibility to evaluate three types of motivations: facilitate commercialization and collaboration with the industry, legal and administrative reasons, reputation building and research related.[8] Results are displayed in Table 3.9. One of the main motivations to patent is to facilitate the commercialization of an invention and to ease collaboration with industrial partners, in that sense patents help academics to build a bridge to reach commercialization activities. However, the impetus may not come from the researcher himself: a high proportion of scientists agreed with the motivation "display the results as asked by the funding agency", and that the process was in fact imposed by a partner company. In that sense, patenting is a response to external pressures. Patenting is often used as a way to measure the success of commercialization activities of university scientists, and as such may be required as a potential output in grant applications and reports. Gaining scientific reputation does not seem to be the principal factor behind patenting, contrary to some results reported in Section 3.2, but it certainly helps to negotiate contracts with industrial partners. Additionally, many evoked

[8]We asked them to grade the statements we proposed to them on a Likert scale according to their degree of agreement: from 0 if they totally disagree and 5 if they totally agree to the statement. Then, we aggregated the answers in three categories. We consider that the respondent agrees with the statement if he gave a mark equal to 4 or 5, that he disagrees for a mark equal to 0 or 1 and that he is neutral for a mark equals to 2 or 3.

the fact that patenting is seen as a means to preserve further development of their research. In these circumstances, they patent their research to prevent being block by others.

Table 3.9: Motivations to patent

What were your motivations for filing a patent?	Disagree	Neutral	Agree
Facilitate the commercialization of an invention through a licensed agreement	14%	26%	60%
To display the results as asked by the funding agency (university or government)	15%	27%	58%
Facilitate the negotiation of collaborations and/or contracts with industrial partners	20%	22%	57%
The process was imposed by a partner company	20%	25%	55%
To protect further development of your research	18%	31%	51%
Increase the visibility of my research in the industrial sphere	37%	31%	31%
Increase your scientific reputation	33%	44%	24%
The process was imposed on me by the IP office of the university or of my department	68%	21%	11%
Increase your income through licenses	53%	36%	11%
Help me to create my company	75%	14%	11%

Note: based on 148 responses.

With Table 3.10 we go a step further, from motivations we move to the consequences of patent applications. Some of the most cited consequences are collaborative research agreements: 61% of the researchers went into collaborative research to help commercialize their invention, and 43% to initiate new collaborations following a patent. On top of that, 29% of the researchers in our sample received extra funding from a company. This is in line with the motivations to patent. Finally, a major discrepancy between intended outcomes and realized ones is to be found regarding license: while a majority of the respondents rank it high in their motivation to patent, only 19% of them have commercialization experience when it comes to licensing inventions.

We also list the results found by Pénin (2010) in the French case to provide material for comparison. The most striking difference regards research collaboration. In the case of Tohoku, the principal consequence of a patent application is the initiation of a collaborative research process to commercialize the invention protected by the patent, in the French case the level is lower (26% compared to 61%). This gives the feeling that this aspect of collaboration is fundamental in the case of Tohoku University. Another important difference with the French results is that none of the Tohoku researchers used patents as a way to facilitate the hiring of their Ph.D. students, which contrasts with the French case.

Table 3.10: Some consequences

Following your patent application(s) what were the direct consequences? (Multiple choices)	Tohoku University	France
Collaborative research to commercialize the invention	61%	26%
New research collaboration with a private company or a public research laboratory	44%	33%
Funding of some of your research by a company	29%	43%
Increase the visibility of my research in the industrial sphere	22%	39%
Commercialization of an invention through a licensed agreement	19%	29%
Increase my scientific reputation	17%	33%
Creation of your company	15%	11%
Hiring of one of your PhD students	0%	27%

Note: the results for the French case were not published in Pénin (2010) but were given to us by the author, the percentages for the French case are based on 274 respondents and 143 for Tohoku.

As a conclusion, patents seem to be a way to foster new or existing industrial collaborations. This is in line with what we conceptualized in Chapter 1: patent is a tool used widely in the industry while publications are used in academia. When cooperating with industry, academics might have to engage in patenting activity to speak the same language as their partners. But, what are the consequences for the academics of altering their languages? Does it change their grammar?

3.4.3 Effects of university patenting: myths and grounded evidence

We asked our respondents what were the negative consequences directly attributable to their patent applications and provided them with different possible negative outcomes. As found by Pénin (2010) in the French case, one of the most pervasive consequences of university patenting is that it induces a lag in the publication process (Figure 3.1). In the French case 78% of the respondent acknowledged a lag in the publication process directly attributable to the patent application. In the case of Tohoku University, the result is also significant: 58% claimed that their publications were delayed by a patent application. 13% declared that at least one of their publications was not published and the same number declared content control. Besides this, we listed as a potential negative consequence of patenting a lesser exchange of information and introduced a distinction among the different potential partners. While the consequences are modest in the academic community and in conferences, 26% feel that patenting is decreasing the level of information exchange with corporate scientists. This in fact might be one of the most negative consequences, as the appropriation of some knowledge by academic scientists makes them wearier in engaging in information exchange with industry at large. It might be good for the commercialization of academic discovery but at the cost of decreasing the number of potential users of university technologies. It is business as usual with the colleagues, but bigger fences are being erected against corporate scientists who are not officially involved in the research in order to protect IP rights and funding opportunities.

Among the inventors who have acknowledged that patents caused a lag in the publication process, around 50% acknowledged a delay of less than 6 months, and 75% state that this delay does not exceed a year, while 25% do not know exactly. This is in sharp contrast with the results found in the French case where in about half of the cases the delay was greater than a year. We were surprised by this difference and asked to few inventors what they would think of a delay superior to one year.[9] They replied than in many circumstances such a delay would "kill" a publication, or at least would be very detrimental to a researcher in a highly competitive field. This result can shed some light to the wider involvement of younger researchers in the case of Tohoku University. However the results are in the same magnitude as the ones found by Blumenthal (1997): around one fifth of the researchers in both studies acknowledge delays longer than 6 months.

In more legal terms, IPRs also seem to have an impact on the research conducted at the university. Table 3.11 tells us a bit more on the subject. 22% of our

[9]We asked this question to all the researchers we interviewed in Chapter 4.

respondents have been involved in a patent litigation while the same percentage have been obliged to reorient their research to get around patents held by third-party organization. Far gone are the times, if ever present, when academics could engage in the free pursuit of knowledge. Among our sample, of serial patentees, legal considerations are taken into account to pursue their research. In our case, researchers scan through patent documents as part of their daily routine. This result differs from the one of Walsh et al. (2005), who showed that in their sample of life scientists, no one was paying attention to patents. At any rate even for those who do not pay attention, legal issues are undoubtedly putting the subject back on the agenda.

Are things changing with the increased reliance on IP? In a survey centered on UIR in Japan, Walsh et al. (2009) tackled this question by asking faculty members whether compared to five years before (from 1998 to 2003), they had changed their likelihood of engaging in behaviors that reflect a rejection of the open science perspective. They found that 30% of respondents say they are more likely to delay publication for business reasons than they were five years ago. Regarding patents, only 3% reported that they are more likely to block their research than was the case five years ago. Some routines are certainly evolving.

3.4.4 Summary of the main findings

So far we have shown that academic patenting was quite an accepted phenomenon among our sample, and that young scientists seem to embrace this practice along with publication practices. Second, patents and industrial collaborations seem to go hand in hand as complementary mechanisms, this result comforts our findings from Chapter 2. Finally, while it is envisioned as a way to increase a researcher's output, it has the negative influence of delaying publications and complicating research through the need to consider legal aspects prior to engaging certain issues.

These elements describe a picture, but from this it is difficult to judge the events thoroughly. In the next section, we will have a more analytical approach and evaluate the influence of a patenting activity on the setting of one researcher's agenda

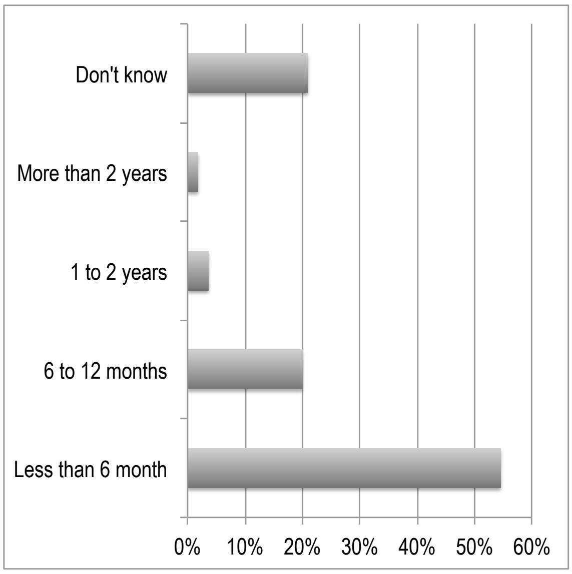

Figure 3.2: Estimated lag in publication date directly attributable to the patent applications

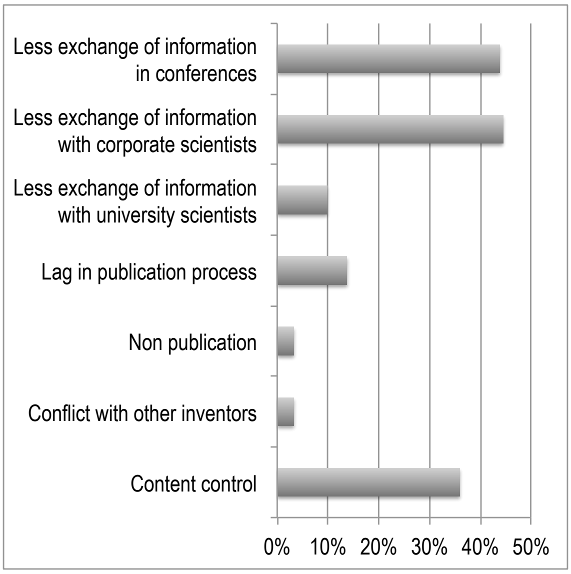

Figure 3.3: Negative Consequences directly attributable to the patent application

and the diffusion of his research. We select these two dimensions as they are essential to evaluate some consequences of patenting. We have seen that patenting is a way to improve collaborative patterns with industry, but have yet to identify which parameters are influencing such a behavior. Research publication is delayed, but does it mean it is also diverted, put under the carpet, and if so what are the characteristics of the scientists diminishing the diffusion of their research for legal and commercial reasons?

3.5 Patenting influence

To examine the data in a more rigorous way, we perform two multivariable Probit regressions. Two dependent variables were used to measure different types of 'deviant' behavior from the norm of open science. We use the term 'deviant' as we are interested in evaluating how patenting may shift academics away from accepted social norms in academia. We want to focus here on how (1) patenting affects the research agenda and (2) its influence on the diffusion of academic research. We have chosen to investigate more closely these two dimensions, as they

Table 3.11: Evaluation of direct negative impacts

Have you already been implied in a patent litigation (Trial, etc.)?	%	Have you already been disturbed in your research by patents held by other inventors?	%
Yes	22%	Yes, I have already been obliged to reorient my research in order to get around a patent held by a tierce organization	22%
		Yes, my lab has already been obliged to buy licenses to other inventors in order to be allowed to pursue research in a given technological domain	3 %
No	78 %	No	75 %

Note: Based on 153 responses

seemed to be central in the literature we surveyed (Section 3.2) and they should shed some light on the results we portrayed in Section 3.4. Indeed, publication delays seem to be an inevitable unintended consequence of the push toward more usage of IP rights in academia, but does this mean that it should affect more broadly the diffusion of knowledge; patents in our case appear to be related to motives of collaboration with industry, but what influence does this setting have on the researcher's agenda? We aim to address this issue by testing what influences a researcher's perception on patenting: individual characteristics such as age, title, productivity, type of research conducted; external factors such as collaboration with industry, work experience in the private sector, or the field of research.

3.5.1 Variables

Dependent variables

The first dependent variable (*influence*) indicates the extent to which patent influence a scientist's research agenda. This variable was derived from the following question in the survey: "*Did the possibility to be granted a patent influence your research?*". The *influence* variable was coded one if a respondent said yes to the question, which was the case for 32% of them. We have shown in Chapter 2 that there is a positive relationship between publications and patenting, however with only quantitative data we could not appreciate the effect of researchers' perception of patenting on the direction of their work. Both activities might be complementary, however this does not tell us anything on the influence that patents exercise on the academic community. Indeed as we have noticed earlier, a key concern is that patenting may skew research priority towards commercial research at the expense of basic research. The fact that 32% of our respondents stated that patenting was influencing their research agenda clearly shows that patents are not a neutral tool in the definition of the research agenda, and as such it calls for a better understanding of this tendency.

The second dependent variable (*restriction to diffusion*) reflects the respondents' decrease in their propensity to share and disseminate research results due to IP issues. It was measured through the following question: *"According to you, does patenting decrease the diffusion and dissemination of academic research?"*. The researchers gave their level of acceptance with the statement using a Likert scale ranging from 0 to 5. To simplify the representation of the results and to isolate very negative and very positive responses, we regrouped them into three categories: disagree with the statement (responses of 0 and 1), a neutral stand (responses of 2 and 3), and agree with the statement (responses of 4 and 5).

Independent variables

This section investigates the effect of three groups of independent variables on deviant behaviors: personal characteristics, research productivity, and industrial involvement.

The first factor we believe that might be important in the analysis is the nature of the scientists' research. The degree to which they see their research compatible with patenting may depend on how it is aligned with the nature of their work. Scientists may specialize in basic, applied research or a combination of both. We use a dummy variable to take this factor into account. We asked the researchers to evaluate the type of research they are conducting. According to their responses we categorized them as *basic researchers* if they responded that they conduct basic research or mainly basic research, *applied researchers* if they responded applied research or mainly applied research and *basic-applied researchers* if they mobilize these two categories while conducting their research. We recognize that the self-reported basis for this variable entails certain limitations on its reliability. The other option would have been to look at the basic or applied nature of journals where they published their results as it has been done in other studies (e.g. Ranga, et al., 2003). However, we feel that our approach leads to a smaller bias as we collect the direct appreciation of the researcher.

Faculty productivity in two areas (publication and patenting) constitutes the second category of independent variables. Our strategy was to create a distinction between highly productive researchers and the others, as it is often showed in the empirical literature that more productive scientists are more likely to combine publication and patenting activities smoothly. In order to identify scientists with *high publication productivity*, we use a dummy variable equal to one when the number of publications, since 2004, has been higher than the average faculty members in his department.[10] We use this artifact to situate individuals' productivity as compared to their close pairs working in the same department. In that way we avoid two caveats: first the inherent difference of productivity among disciplines and second the need to control for heterogeneous levels of publications between departments. For the variable *high patent productivity*, we create a dummy variable equal to one if the scientist has declared to be involved in more than five patents in his career; we used this number as it was the highest level researchers could give in the survey. We could also have used the number of patent the researchers have been involved with since 2004,[11] but that way the responses to the survey span over the entire career of the researchers and therefore provide a better idea of that lifelong involvement in patenting.

Our third type of variables look at the effects of working with the industry. We have created a variable equal to one if the researcher had *industry work experience*, which we extracted from the survey. We use a dummy variable to identify and control for scientists who have been involved in one or more *industrial research collaboration* since 2004.[12] These variables are introduced to take into considera-

[10] This result was calculated with the data of Chapter 2. Almost identical results were obtained by running the regressions with the number of publications.

[11] As explained in Chapter 2, we have difficulties to trace academic patents before the Incorporation of the university.

[12] This information comes from the data gathering work that was conducted for Chapter 2. We

tion the role that experience of working with the industry has on the judgment of patents.

Control variables

We include discipline dummies to see whether the research field has an influence on the way patenting affects the research agenda and on the diffusion of knowledge. We use an additional dummy variable to identify scientists who are full *professor*, specifically to control for the possible impact of having an influential position and hence being free to define their research agenda. Finally, we control for the respondent's age, given that attitudes towards patents may vary accordingly. Summary statistics of the variables are given in Table 3.12

3.5.2 Results

In order to test the first dependent variable, the influence factor, we use a Probit model, as the variable of interest is binary. For the second variable, the restriction to diffusion, we use an ordered Probit model because of the ordinal nature of the dependent variable. The results of the regression are displayed in Table 3.13.

- **Perceived impact of patenting in influencing research**

The results of the first regression show that researchers conducting applied or a combination of basic-applied research are more likely to have their research influenced by patenting considerations. The variables indicating collaboration with industry are not a significant predictor of the perceived impact of patenting. Our dummy variable measuring *Medical science* shows that academics in that field are more likely to be influenced than the ones from our benchmark group engineering. Alternatively, we have reordered the field variables in three categories: engineering, physics and chemical science, and a life science variable encompassing medical science, biology and pharmaceutical science. We found similar results: the life science dummy has a significative impact. This result is in line with the literature: members of the life science disciplines are more likely to be influenced by patent considerations in setting their research agenda than researchers in other fields.

choose 2004 as a starting date, as it is the oldest year we could retrieve.

Table 3.12: Summary statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Influence	158	.32	.47	0	1
Restriction to Diffusion	130	1.82	.75	1	3
Basic Research	158	.26	.44	0	1
Applied Research	158	.44	.49	0	1
Basic & Applied Research	158	.28	.45	0	1
High Publication Productivity	158	.58	.49	0	1
High Patent Productivity	158	.49	.50	0	1
Industry Work Experience	158	.28	.45	0	1
Industrial Research Collaboration	158	.63	.48	0	1
Professor	158	.49	.50	0	1
Age	158	49	10	30	71
Engineering	158	.50	.50	0	1
Physics	158	.08	.27	0	1
Chemistry	158	.15	.36	0	1
Medical Science	158	.16	.30	0	1
Life Science	158	.07	.24	0	1
Pharmaceutical Science	158	.04	.19	0	1

- **Perceived impact of patenting in the diffusion of academic knowledge**

Our question was negative in essence: we asked if patenting had a negative impact on the diffusion of academic knowledge. Therefore, we have to be cautious when interpreting the signs of the regression. Researchers who are conducting basic and applied research are more likely to be skeptical about the idea that patenting decreases the diffusion of academic knowledge. Therefore basic researchers are more likely to have a negative perception about academic patenting regarding an unconstrained diffusion of their research. Highly productive researchers, related by their number of publications, are unlikely to see patenting as a factor impeding the diffusion of their research.

Our dependent variables on industrial collaboration do not have any significative impact. As for position and age, professors are more likely to agree with the statement that the age variable is positively and significantly associated with the dependent variable. Age increases the likelihood that a scientist will see patenting as a factor diminishing the diffusion of academic knowledge. As the change in IP policies are relatively new in the Japanese context, we may argue that this view is

Table 3.13: Probit and ordered Probit regression results on (a) the influence of patenting on the research agenda and (b) on the effect of patents in the diffusion of academic research

Independent variable	Probit Model (Influence)		Ordered Probit Model (Restriction to Diffusion)	
	Coef.	Std. Err (Robust)	Coef.	Std. Err (Robust)
Applied Research	0.84**	0.29	-0.31	0.26
Basic & Applied Research	0.65*	0.31	-0.68*	0.31
Industry Work Experience	0.26	0.25	-0.17	0.23
Collaboration with industry	-0.01	0.26	0.04	0.24
High Productivity Publication	-0.30	0.23	-0.46*	0.22
High Productivity Patent	0.19	0.24	-0.05	0.22
Professor	-0.28	0.32	0.67*	0.33
Age	0.01	0.01	0.04**	0.01
Physics	-0.52	0.45	-0.11	0.41
Chemistry	0.47	0.30	0.06	0.31
Medical Science	0.75*	0.33	-0.24	0.29
Biology	0.17	0.46	-0.14	0.49
Pharmaceutical Science	0.22	0.66	-0.48	0.51
–cons Intercept 1	-1.71*	0.72	-2.78***	0.75
——— Intercept 2			-1.57*	0.73
Pseudo R2	0.11	0.07		
Wald chi2	(13) 21.80		(13) 18.72	
log pseudo-likelihood	-88.67		-146.91	
Number of observations	159		128	

Note: Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.
All regression results are reported with robust standard errors. Running regressions with robust standard errors only entail small changes to the p-values, suggesting that the models do not suffer from important heteroscedasticity problems.

correlated with the possible negative changes in terms of free flow of information, compared to a system where patenting is playing a less important role. This result about the influence of the age factor in evaluating the effect of patenting is a recurrent element in our analysis. In the quantitative analysis we have conducted in Chapter 2, we found that the younger cohort of researchers was more actively engaged in patenting than their older peers. Clearly, from these converging elements, we can argue that the reactions to the new legal environment framing technology transfer activities of universities, a environment more favorable to IP, are different depending on the age of the researcher.

3.5.3 Discussion

The main findings of the regressions are the following. First and foremost, researchers who combine both applied and basic research are at the same time designing their research agendas to favor the apparition of patentable results and are significantly less skeptical about the impact of university patenting on academic diffusion of knowledge than their colleagues. At the same time highly productive scientists in terms of publications are significantly less skeptical about patenting regarding the diffusion of their research. A second important result is that the existence of a research contract with an industrial partner, and the fact that the researcher has had work experience in the private sector, do not seem to have an influence on our two parameters: influence on research choices and free diffusion of knowledge. This result is in line with Ranga et al. (2003) who studied the influence of business partner's needs in a Belgium university. They did not find generalized evidence of a shift in research by academics involved in UIR. Third, we found that older researchers and professors were more likely to see patenting as a factor that diminishes the free diffusion of academic knowledge. This could be reflecting the changing patterns of UIR and patenting in Japan, older academics perceiving these changes as detrimental to the mores of science. This is in line with the results from Walsh et al. (2009) who found that there has been a significant increase in commercial activities by Japanese universities in the recent period influencing the behavior of faculty members.

Finally, we found that the nature and the field of research were factors influencing the perception of academic patenting on academic choice. Basic researchers are significantly less likely to see university patenting as a factor guiding their research, and scientists in the life science sector are more likely to take into consideration patenting in setting up their research agenda. These two dimensions are shaping the way academic researchers are responding to patents. Davis et al. (2009) conducted a similar study on academic life scientists in Denmark. They investigated the effect of academic patenting on academic freedom and the norms of open science. They found that scientists who are predominantly oriented towards basic research are more likely to be negative towards the effects of university patenting on academic freedom, while highly productive researchers are significantly less skeptical. On the question of commercial motivations, Mowery et al. (2001) in analyzing the changes resulting from the Bayh-Dole Act found that areas in which university research has grown rapidly have been rich in results with commercial promises. They suggest that the content of US universities' research has shifted towards biomedical research may be a cause rather than a consequence of university patenting. It might be the new opportunity of commercialization offered in the field of life sciences that lures academics to patent. In our next chapter, we will investigate more thoroughly these dimensions as core elements to consider when analyzing UIR.

3.6 Conclusion

The results of the survey brought about many interesting results that lighten up our understanding of the motivations and consequences of academic researchers to patent. Briefly stated, the important points of this chapter are the following. First, we have shown that patenting is a practice younger researchers at Tohoku University are engaged with. They notably show signs of appropriating its norms while maintaining the idea of free and rapid diffusion of knowledge. This attitude might be fostered by the relatively good perception of the activity by our respondents' colleagues. In that picture, high achievers show signs of being more successful in balancing the specific needs of each activity, a result that has been portrayed in many ways in the literature. Second, the main motivation and consequence to patent lies in the willingness to foster industrial collaborations as they are seen as a way to bring in cash, knowledge and to facilitate the commercialization of inventions. Although, having experience with industry does not look to be a factor influencing the research agenda of scientists and their propensity to disseminate their knowledge, its influence might be subtler. On the negative consequences of patenting, like other studies, we found that delays in publications are major unintended effect of patenting. We are, as well, concerned by the relatively high number of respondents who declared to have been involved in patent litigations or changed their line of research due to patents held by third-parties. Finally, our findings show that a distinction exists between researchers who subscribe to a traditional, Mertonian approach to research, and researchers who take a more applied, commercially oriented approach to university research. Researchers belonging to these two worlds, we believe, have experienced the increased use of patent by universities very differently. While researchers who can mix applied and basic consideration in their work apparently care little about the increasing use of patents, at least some of the low performing scientists and basic researchers may apprehend the story differently.

However this picture is only partial, as we cannot exclude the possibility that non-respondents may have differed from respondents in ways that biased our results. Additionally, we relied on self-reported behavior, which may increase the possibility of response biases. Faculty may have under-reported engaging in behavior that they viewed as contrary to accepted norms of practice. Faculty may also have a tendency to over report reasons they view as socially acceptable. For example, faculty may have felt more comfortable responding to our inquiry following the university policy line. For instance, many have reported licensing of a discovery as a reason behind patenting, however, many have not had opportunities to license *per se*. In spite of that, the results portrayed in this chapter may be informative for policy makers. Indeed, understanding scientists' motivations for patenting, and the influence that act has on the choice of their research agenda is crucial in order to be able to design adequate incentive schemes for scientific research. In particular, the difference of perception and usage of patenting among scientists of different age, productivity and consideration for practical use of their discoveries, is an important element to consider when implementing measures to foster the use of IPRs in academia.

In the next chapter, we will look in more depth at how IP and commercial considerations influence the work of a selected group of prolific researchers in the field of materials science and engineering. We use this field of research as it is a field of excellence at Tohoku University, and is prone to industrial interest and collaborations, while providing a benchmark to the well-documented case of the life sciences. Using Stokes' (1997) classification of research as a guideline, we will investigate how different types of research practices shape faculty decision and their way of commercializing their discoveries.

CHAPTER 4

WHAT WE CAN LEARN FROM ACADEMICS ABOUT UNIVERSITY-INDUSTRY COLLABORATIONS IN THE FIELD OF MATERIALS SCIENCE

Studies of scientific activity by economists and sociologists are often concerned with numbers of publications and with duplication of effort. While such examinations are of some value, they leave much to be desired because, in part, the statistical tools are crude and these exercises are often aimed at controlling productivity and creativity. Most important, they are not concerned with the substance of scientific thought and scientific work.

— Latour and Woolgar (1986)

4.1 Introduction

In Chapter 3, we looked at the picture portrayed by academic inventors at Tohoku University. We found that these inventors were trying to combine commercial imperatives within an open science framework; that the perception of patenting activity was quite favorable within the community; and that one of the main functions of patenting was to secure industrial collaborations. In this chapter, we want both to be more precise, by looking in-depth at a selected number of researchers, and more wide-ranging by investigating industrial collaborations' influence, not only on patents but on the work of scientists. A case study approach based on interviews and archival records will be adopted to achieve this goal.

The main objective of this chapter is to analyze how university-industry relations (UIR) affect the research practices of academics. In addressing this theme we will put forward two dimensions: the differences among scientific disciplines and the differences in research goals, as measured by Stokes' classification. These dimensions are important to consider as little attention has been devoted to understanding mechanisms at play in different research fields and among different type of scientists. Science includes many distinctive intellectual traditions and disciplines, which is often overlooked in the economic and management literature on UIR. As the Latour and Woolgar quote above reminds us, not enough attention is paid to the "substance of scientific thought and scientific work". For instance, many quantitative studies limit their analysis of the field to a dummy variable in regression analyses, together with a strong tropism towards life science disciplines in a majority of the qualitative studies focusing on UIR. However, we feel that the mechanisms at play in UIR vary according to disciplines. Indeed, it is crucial to take this dimension into account since the innovation/discovery process differs across scientific fields depending on the knowledge base they build upon. By advancing the knowledge on UIR, biotechnologies and related fields in pharmaceutical science have attracted much attention. In these domains, the contribution of science is found to be substantial, particularly when new ideas developed within university laboratories are quickly captured by industry. Our intention here is to detail another domain by shedding light on the practices in materials science and engineering (MSE). We chose this area for three reasons: first, it could be used to benchmark results found in life sciences; second, we argue that the UIR are widespread in this field; third, it is an area of excellence in our unit of analysis, Tohoku University. Furthermore, we wanted to test whether the responses to UIR challenges were even amongst different types of researchers. In our view, the type of research a scientist is conducting has to be taken into account to explain the different ways an academic researcher interacts with the industry. In that respect, following Stokes (1997), we categorized a researcher's work both on the degree to which it seeks to extend the frontier of fundamental understanding, and the degree to which this research is guided by consideration of use.

In this chapter, we investigate how UIR affect academic research. We deploy an inductive qualitative research approach because the evidence of such impacts are very thin in the field of MSE. Our primary purpose is to understand the effects of industry involvement on academic researcher's work while being relatively open to the results and variations according to the type of research undertaken by a scientist. The chapter is organized as follows. First, drawing on scattered pieces of the literature, Section 4.2 highlights the need to consider the fields' characteristics in approaching our subject. We then provide details on the data and methods employed (4.3), and present our findings (4.4). We conclude with a discussion of our results in light of the literature (4.5).

4.2 All about life sciences?

4.2.1 Industrial collaboration and academic life sciences: the emerging dominant evidence

Empirical efforts have been made to evaluate the consequences of UIR on academic scientists' productivity, ethics, and choice of subjects, with a majority of this effort revolving around the field of life sciences (e.g. Azoulay, et al., 2007; Blumenthal, 2003; Davis, et al., 2009; Walsh, et al., 2005; Zucker and Darby, 2001). This hardly comes as a surprise as academic science is the foundation of the biotechnology industry (Kenney, 1986), and as such is still reliant on public science, specifically basic public science (Narin, et al., 1997). Powell and Owen-Smith (2002) argue that academic and commercial life scientists are turning into a single technological community. Borders are more permeable, the connections between the two communities are becoming more and more intense and diversified. As they phrase it:

> [L]ife sciences are a novel case where basic research continues to play a fundamental role in driving commercial development, integration between basic and clinical research is ongoing, and private firms have a hand in basic science and universities in downstream clinical development (ibid., p. 114).

In the same vein, based on interviews with both academic, corporate scientists, and administrators from life science disciplines, Vallas and Kleinman (2008) tell a story where the normative constructs found in commercial and faculty laboratories are becoming more alike. Their study provides evidence that the culture of university science has incorporated the entrepreneurial ethos. They notably lament over the rise of this entrepreneurial ethos in academic science, which in their view impedes the free flow of information, even without the use of intellectual property. For them, it is the "sharpening competition for professional distinction, combined with the entrepreneurial ethos driven by the scramble for scarce dollars, which has yielded increasingly potent barriers to the sharing of knowledge among scientists" (ibid., p. 16).

These stories and descriptions, among others, are informative but they only explain the mechanisms at play in one field: life sciences. Our point here is that this de facto field-centered approach creates some confusion in the perception of UIR. In many papers, generalizations are made from this specific field of research. For instance, Azoulay et al. (2006, p.621) hastily conclude, "results suggest that the academic incentive system is evolving in ways that accommodate deviations from traditional scientific norms of openness. [...] This finding dovetails with qualitative accounts that emphasize that patents are becoming de rigueur on academic vitas in many institutions...". Such conclusions neglect to take into account UIR in others fields, which negatively affect our ability to describe these phenomena more generally. Are these trends the same in all disciplines? Is nanotech the next biotech? Do physicists and engineers face the same dilemma and opportunities than life scientists? We intend to address these questions in this chapter by documenting a case in the field of MSE. In order to compare both fields, the next section will summarize some of the key findings in life sciences to create a benchmark we intend to compare our results with.

4.2.2 Creation of a benchmark

The success and fast growth of many biotechnology companies have generated a vast literature on the subject. Scholars have carefully studied the emergence and evolution of the biotechnology industry, in general, and the close interaction between public research and industry, in particular. Under the impetus provided by this abundant literature, the whole life science sector has been under close scrutiny. This section selects some elements from this literature that we will then use to compare with MSE. We gathered the different categories we want to analyze in Table 4.1.

The first level examines the effect of UIR on academic freedom, a topic we have extensively written about in the previous two chapters, so we will not comment on it here. The second dimension refers to the new career options proposed to an academic, which originate from the rapid expansion of what we call *academic capitalism*.[1] For instance, new employment opportunities for academic scientists are becoming frequent in industry (Colyvas, 2007; Kenney, 1986; Vallas and Kleinman, 2008; Zucker, et al., 1998). The mobility of academics towards industry and industrial positions, such as being listed on companies board committees, is becoming widespread. For example, Krimski (1991) reports that out of the 359 biomedical scientists who were members of the US National Academy of Science, 37% had formal ties with the biotechnology industry, and that 31.1% of faculty at the MIT department of biology were sitting on the scientific advisory board of at least one biotech company. The phenomenon is so pervasive that some books even cater to the needs of academics who consider such reorientations (Gimble, 2005).

Along with this increased mobility, academic patenting is very present in this research field as it is a way to attract money and to protect one's own research. More generally, life sciences are the locomotive of patenting in academia, as it accounts for a sizable share of its increased number of patents. This practice is well-rooted among academics in life sciences, a comment of Nobel Laureate Arthur Kornberg, famous for his works on the biological synthesis of DNA, illustrates this: "Every one of us working in a laboratory [...] have to wonder whether anything we do may have been protected by a patent and whether we will be sued for it".[2]

[1] Slaughter and Leslie (1997) coined the term, referring to how universities have expanded technology transfer activities, developed UIR, marketed their research discoveries, promoted the formation of start-up companies, and generally pursued a shift in emphasis to producing research for commercial applications.

[2] As cited from Powell and Owen-Smith (1998).

In a similar line of inquiry, many studies portrayed scientists with ties to industry as more productive than the ones without. One consequence of this phenomenon is that market-based criteria become the dominant logic in resource allocation decisions. Scientists studying issues similar to market themes have easier access to research funds, more opportunities to network with companies' scientists and researchers in hospitals and public research organizations. The sharing of materials, scientists, and data is based on formal and informal networks, where those who are not connected will have their research hampered. On top of that, the norms and conducts of doing science seem to be converging between the members of the networks, as the academic and commercial reward systems are becoming increasingly similar.[3]

4.2.3 Materials science and engineering

We chose materials science and engineering (MSE) in order to widen the perspectives provided by the narrow focus on life sciences in much of the previous literature. In life sciences, intellectual property rights (IPR) play an important role, therefore many studies within this field focus on patenting and licensing. In other disciplines, such as engineering, collaboration is seen as being more important (Schartinger, et al., 2002). As we have stressed, a large amount of empirical work has been focusing on life sciences. As a result many elements of UIR have been explored in this field. In our view, it is important to consider other disciplines and determine whether the hypotheses put forth for the life sciences hold for other contexts.

In this section, we justify the choice of MSE as a counterpart. The first reason is opportunity. Indeed, MSE are a field of excellence at Tohoku University. There are two research institutes focusing on the issue, The Institute for Materials Research (IMR) and The Institute of Multidisciplinary Research for Advanced Materials (IMRAM) and many laboratories from the Graduate School of Engineering.[4] Members of these units are generating the largest number of patents and are among the most

[3]Chapter 5 analyzes rigorously the convergences between academia and industry.

[4]IMR see at http://www.imr.tohoku.ac.jp/eng/ and IMRAM at http://www.tagen.tohoku.ac.jp/en/

Table 4.1: Effect of commercialization on academic life scientists

Categories	Effect	Sources
Academic Freedom	–Delay in publications –Restriction in publications –Refusal to share research materials –Merging of academic and commercial reward system	–(Blumenthal, et al., 1996) –(Bekelman, et al., 2003) –(Walsh, et al., 2005) –(Vallas and Kleinman, 2008)
New opportunities	–New employment opportunities for academic scientists in the industry –New resources: the bulk of both issued patents and revenues result from innovations in the biomedical field	–(Colyvas, 2007; Kenney, 1986; Vallas and Kleinman, 2008; Zucker, et al., 1998). –(Henderson, et al., 1998; Mowery, et al., 2001
Role of patents	–Help academics convince firms to pay for developmental research –Protect academic freedom from commercially held patents	–(Owen-Smith and Powell, 2001)
Research Productivity	–Scientists with ties to industry or entrepreneurial activities have comparatively higher productivity	–(Azoulay, et al., 2007; Siegel, et al., 2007; Zucker and Darby, 2001)
Effect on the research agenda setting	–Market-based criteria become the dominant logic in resource allocation decisions.	–(Powell and Owen-Smith, 1998)
Motivation	–Response to resource dependence: Need for cash –Access network of exchange between scientist from academia, companies, and hospitals	–(Slaughter and Leslie, 1997) –(Audretsch and Stephan, 1996; Liebeskind, et al., 1996; Powell and Owen-Smith, 2002; Vallas and Kleinman, 2008)

productive in terms of publications. As a further proof of its excellence in the field, the university is ranked as the number three institution in the world in terms of publications and citations for the period 2000-2010, with respectively 5,542 papers and 41,174 citations.[5]

The second reason, which carries more weight, is that there is evidence suggesting a strong relation between industry and university in this field, rending it an appropriate subject for comparison with life sciences. Historically, the emergence of academic research in this field has been paved by industrial research. Indeed, a few corporate laboratories were already applying the ideas of MSE before it was taught as an independent subject at universities, and even before these disciplines acquire a name. This was true in particular of William Shockley's group at the Bell Telephone Laboratories and also of General Electric Research Laboratory. W. Shockley - a Nobel laureate - and his team elaborated on the foundations of early semiconductors with their development of the transistor in 1947. In that period, the managerial settings were conducive to cutting-edge research, and Shockley had great freedom to pursue his task as exemplified by the scope of his 1945 authorization for work that requested him to seek "new knowledge that can be used in the development of completely new and improved components" (Lojek, 2006, p.14). Accordingly he could hire top scientists from the industry or university to attain this goal. More generally, the Bell Laboratories had at the time a solid interdisciplinary team composed of top-flight solid-state scientists, together with metallurgists who played a major role in the advancement of pure crystal production needed for the development of transistors (Nelson, 1962). In this period, the links between industrial and academic researchers were strong, and the communities were working closely together. In parallel, the impetus to formalize the training in the field was present when in 1959 Northwestern University (Illinois) was the first academic institution to adopt materials science as part of its curriculum. This move was initiated by Morris Fine, a metallurgist conducting research at Bell Laboratories, who proposed to integrate materials science in the curriculum when he was consulted in 1954 to discuss plans to create a new Graduate Department of

[5]Source from *Essential science indictors* by Thomson Reuters: http://esi.isiknowledge.com

Metallurgy (Cahn, 2001).

Thus, MSE is a relatively new field of research. It emerged in the 1950s as a new scientific discipline born out of metallurgy. A prominent researcher described it in the following way: "Out of metallurgy, by physics, comes materials science". It was denominated as such in 1956 by a group of leading American scientists, although no one specific individual may be identified as having coined it for the first time. It can be seen as a scientific paradigm representing a broad synthesis from a number of older, narrower fields: metallurgy, solid-state physics and physical chemistry. It investigates the relationships between the structure of materials at atomic or molecular scales and their macroscopic properties. The key justification of the whole concept of MSE is the mutual illumination resulting from research on different categories of materials. This interdisciplinary approach and cross-fertilization are at the center of the field's research strategy. Cahn (2001), in a seminal contribution on materials science, describes the discipline in the following manner:

> Materials are highly diverse, yet many concepts, phenomena and transformations involved in making and using metals, ceramics, electronic materials, plastics and composites are strikingly similar. Matters such as transformation mechanisms, defect behaviour, the thermodynamics of equilibria, diffusion, flow and fracture mechanisms, the fine structure and behaviour of interfaces, the structures of crystals and glasses and the relationship between these, the statistical mechanics of assemblies of atoms or magnetic spins, have come to illuminate not only the behaviour of the individual materials in which they were originally studied, but also the behaviour of other materials which at first sight are quite unrelated. This continual cross-linkage between materials is what has given rise to Materials Science (ibid., p. 527)

As such, we can argue that MSE is a multi-disciplinary field with an emphasis on the comprehension and creation of new materials, qualities that are of great interest for the industry, besides constituting the origin of the discipline. More precisely, using data from the Carnegie Melon Survey, Cohen et al. (2002) showed that materials science has the most pervasive direct impact on industrial research and development (R&D). Half or more of industry respondents scored materials science no less than "moderately important" to their R&D activities in 15 of 33 manufacturing industries they have studied, spanning from chemicals, metals, electronics, machinery, to transportation equipment industries. Interactions in the field are high between university and industry; making it a potentially fertile area to explore.

Although, few studies have looked in detail at UIR in this field, the work of Baba et al. (2009) is an illuminating one. At the center of their analytical framework is the concept developed by Asheim and Coenen (2005), who argue that innovation processes are particularly dependent on their specific knowledge, which could be *analytical* or *synthetic*. They define analytical knowledge as a process which builds on formal scientific bases where knowledge creation is often based on cognitive and rational methods, or on formal models. These types of mechanisms are common in genetics, biotechnology and general information technology. They note that input and output of this type of knowledge are often codified. On the other hand, synthetic knowledge takes place mainly through the application of existing knowledge or through new combinations of knowledge. It often occurs in response to the need to solve specific problems, where interaction between the different actors involved is needed. In that setting, tacit knowledge is as important as cooperation is essential to problem solving. These types of mechanisms are common especially in the field of engineering.

Baba et al. (2009) argue that materials science is original as it features both synthetical and analytical knowledge bases. This fact is of particular importance in the analysis of UIR in this field. Indeed, radical innovation in advanced materials involves commercializing new knowledge generally created by universities or government laboratories, which could be labeled as analytical. But the commercialization process faces the hurdles of replicating laboratory attributes in product prototypes and viable productions processes. This second step is costly, lengthy, and requires repetitive interactions between the different partners involved in the first models and prototypes (Maine, et al., 2005; Williams, 1993).

In that respect, Maine and Garnsey (2006) provided a detailed account of two start-up companies that were created to commercialize advanced materials originating from research universities. Both entailed many interactions with universities and needed a rather long time (10 years) to move from prototypes to commercialization. A comparable account of events is given by Baba et al. (2009) in their story of two prolific researchers from Tokyo University, who discovered fundamental properties of a new material needed for photocatalysis.[6] One of the interesting points of their analysis is that these two scientists were eager to work with industry to find applications of their discoveries while the industry wanted to tap into their scientific understanding of photocatalytic phenomena.

> Consulting is a two-way interaction mode between scientists and corporate researchers, whose nature has to be found in the reciprocal expectation of gaining some advantages. Industry partners normally receive from universities a deeper understanding of the nature of scientific phenomena. [...] Academic partners normally engage in U–I collaborations to gain access to complimentary assets needed to advance their scientific activities. The partnership is often seen as a means to overcome the limits of universities' process technology for testing a scientific hypothesis, or to receive financial support. (ibid., p. 759)

The close link between academic and industrial materials science was portrayed here by specifying different key elements of the relation: a long history of UIR, pervasive impact of academic science on university research, and specific knowledge characteristics that rendered it fertile for UI cross-fertilization. Indeed, in the field of materials science, the mechanism of cooperation is peculiar as there is a need of end-user information to develop new materials. In that sense university scientists need access to corporate research insights to develop new materials and applications, and corporate scientists are in demand of scientific explanations on the phenomena they are investigating. Since the nature of collaboration in materials science is bilateral, a "two-way" interaction model seems to fit the relation between university and industry (Meyer-Krahmer and Schmoch, 1998). For these reasons, we are confident that it is useful for the UIR community to deepen our understanding of the field through comparison with life sciences.

4.3 Methodology

Having laid down the setting, we now address our research question more precisely and explain how we intend to address it.

[6] Photocatalysis is the acceleration of a photoreaction in the presence of a catalyst.

4.3.1 Research question

We intend to investigate the effect of industrial collaborations on the way academic researchers organize their work. Our main research objective is to gain a better understanding of the influence of industrial collaboration, be they formal or informal, on the organization and dissemination of university research. The organization of academic research is a complex system responding opportunistically to changing circumstances. We argue that these changes are the product of expediency, not design. A central feature of our analysis is the recognition that streams of knowledge are embedded in distinctive institutionalized spheres – public and private – that shape the rules of knowledge disclosure, access and reward. In addition, we argue strongly against any universally valid, "one-size-fits-all" models. We think that there is a need to use a differentiated approach according to the type of research and the discipline under scrutiny.

By conducting an in-depth analysis of the research activities of academic researchers in MSE, we wish to achieve a better understanding of three dimensions. (1) What are their motivations to work with industry? (2) How do they collaborate? (3) And how does industry involvement influence the way they diffuse their results and choose their research topics?

4.3.2 Case study approach

Our research question for this chapter is a "How" type. Inductive research is often used to research such questions. Moreover, as our area of interest, the impact of UIR on university-based MSE, is relatively understudied we decided to use case studies to approach our research questions (Yin, 1994). The case study method enables us to understand more thoroughly the dynamics that define this research setting. We collected information on different types of university–industry collaboration by interviewing participant-informants. Using theory-driven sampling (Eisenberg, 1989), we identified academics involved in commercialization activities.

We chose to focus on university scientists with industry contacts in order to tap into their working knowledge and experience regarding formal contractual arrangements and informal contacts. In doing so, we intend to grasp the nature and impacts of UIR on the conduct and organization of faculty research. In order to identify such scientists, we used data on patent and contractual research with industrial partners. Our first filter to qualify as an interviewee, one had to have been involved in a patent and contract at least once during the 2004-08 period. Second, we decided to choose highly prolific scientists. A scientist who publishes only a paper a year and has been involved in only one patent, may be interesting to talk to, especially to collect his view on UIR as he is embedded in the research community, but we believe that prolific scientists may provide more information on the phenomena. In that line of thought, Patton (1990, p. 169) argues that "[t]he logic and power of purposeful sampling lies in selecting information-rich cases for in-depth study. Information-rich cases are those from which one can learn a great deal about issues of central importance to the purpose of the research, thus the term purposeful sampling".

4.3.3 Selection criteria: discipline and type of research

Table 4.2: Selection criteria

	Academic criteria	Industrial criteria
Bohr scientists	High level of publication	Low level of patents
Edison scientists	Low level of publication	High level of patents
Pasteur scientists	High level of publication	High level of patents

We selected our respondents using two dimensions: discipline and research type. We limited our sample to the population of scientists specialized in the field of MSE at Tohoku University. Additionally, we look for a way to differentiate the researchers based on the type of research they are conducting. As established in the previous section, we are looking for high achievers, researchers combining high productivity and relations with the industry. But how does one effectively take into account different profiles regarding UIR? We have decided to use the classification developed by Stokes (1997), as it enables to categorize three types of researchers: Pasteur, Bohr and Edison. (See for more details Chapter 1, Section 3.1.). Following and adapting the method developed by Baba et al. (2009), we used two dimensions to operationalize Stokes' classification, patenting and publishing. As we already mentioned patents and publications are often used to measure the productivity of a researcher, on top of which they have the advantage of indicating indirectly the commercial or academic inclinations of scientists. The first group identifies and labels outperforming university scientists as “Bohr scientists”; they reported a high level of publication, but a moderate patenting activity. The second group, called “Edison scientists”, consist of scientists who showed a high level of patenting activities, but a relatively modest level of publication. Finally, the third group, named “Pasteur scientists”, consists scientists that report both high level of publications and patents. The criteria are summarized in Table 4.2. More precisely, we used the data we collected for Chapter 2, within the field of MSE, and chose the highest performing scientists in terms of publications who also had experienced at least one patent as Bohr scientists. The Edison scientists were chosen among the highest patentees who had a relatively low level of publication, while the Pasteur scientists both exhibited high level of publication and patent.

4.3.4 Description of the interview process

We sent a request for interview to 15 researchers (5 in each category) based on our criteria, out of which 10 replied positively and agreed to meet us. We conducted 10 one and half hours semi-directed interviews in the second half of 2009, which were all recorded and transcribed. All the interviews followed the same pattern. First, we explained our work and how we selected them. We subsequently let them explain their research, enquiring on four different topics:

(1) First, we asked about their direct activity in the scientific and technical community including publications, conference proceedings, patenting. In that part we asked them to give examples of their collaboration with industrial partners.

(2) Next, we asked them to explain the organization and direction of their research team. We inquired about the size of their team, its organization, and research topic selection.

(3) We specifically asked them to describe some precise collaboration with an industrial partner, and inquired about their motivations to engage in such a collaboration.

(4) We asked how their collaboration was impacting on their publication activities and how they appreciated academic patenting.

We adopted various measures to improve validity. We prompted interviewees for facts rather than opinions to reduce cognitive bias. For instance, we asked what exactly posed barriers to the writing of scientific articles when collaborating with industry. Additionally, respondents were promised confidentiality in order to improve the accuracy of answers. Table 4.3 presents an overall view of our interviewees, as it displays information on their publication and patenting activities, identifying their Graduate school or Institute affiliation, and providing keywords representing their main theme of research for the period 2004-08 .[7] To keep anonymity we coded the name of the researchers. For instance, B.1 stands for the first researcher we interviewed belonging to the Bohr type. It is important to notice that the researchers we interviewed and labeled as Edison and Pasteur type are among the most prolific patentees in the University. Out of 808 faculty members in the science and engineering departments, they are among the 17 researchers who have been listed on more than 10 patents during the period 2004-08 (Chapter 2, Table 2.4).

In the next three sections, we will quote the most important points drawn from the narratives collected during our interviews. The main objective of this exercise is to gain a better understanding of how they work and integrate commercialization dimensions and industrial collaborations in their research. These elements will then be summarized and put into perspective in the discussion section.

[7]Before the interviews, we searched for the respondents CVs, publications and website. From this information we gathered keywords potentially characterizing their research. When we met them, we showed them the list and asked them to choose the keyword most accurate to describe their work.

Table 4.3: Information on the interviewees

Researcher	Affiliation	Field of Research	Publications Publications 2004-08	Impact Factor	Co-publications with industry 2004-08 (Different companies)	Industrial contracts 2004-08 (Different companies)	Patents 2004-08
Average Scientist			13.21	27.91	–	–	1.28
B.1	IMR	Material Design	225	600	41 (10)	6 (4)	1
B.2	IMR	Organic conductors	181	246	22 (4)	2 (2)	2
B.3	IMR	Superconductors	88	324	18 (4)	3 (2)	1
E.1	Engineering	Semiconductors	10	18	9 (7)	22 (11)	25
E.2	Engineering	LCD	8	8	6 (4)	26 (8)	65
E.3	Engineering	Carbon Nanotubes	24	54	18 (8)	11 (9)	14
P.1	Engineering	Metal alloys	103	412	6 (8)	4 (3)	61
P.2	IMRAM	Crystal Materials	59	96	14 (10)	10 (5)	25
P.3	IMR	Oxide electronics	153	540	22 (8)	26 (5)	45
P.4	IMRAM	Nanoparticules	41	76	7 (11)	23 (8)	10

4.4 Case description

4.4.1 Bohr

> "I am not interested in patents, but I let companies apply for them with my name in it."
> Researcher B.1

Serendipity is required for successful research. While describing our research and the Stokes' classification, we came upon an interesting anecdote, certainly known by physicists but unheard of by people outside the field. One researcher was amused by our choice; or rather Stokes' choice of Bohr, one of the fathers of quantum physics, as an eponym representing researchers far from practical concerns. Researcher B.2 told us that "Quantum physic started from the steel companies who needed to measure the temperature of the melting steel within a furnace. Put it simply, while investigating this problem they realized that something was strange and then came quantum physics". Indeed, the introduction of the new concept of quantization was a consequence of Max Planck's effort to interpret experimental results related to black body radiation. This phenomenon involves interaction between light and heat, and it attracted a lot of attention in the latter part of the nineteenth century as it was in great demand by the German industry that promoted the problems of high temperature and thermal radiation. Indeed, one practical application was the improvement of the furnaces that produced iron and steel (Cahan, 2005, Chap. 4; Taketani and Nagasaki, 2002). Respondent B.2 humbly told us that he was envisioning his relations with industry in much the same way: "New technology produces new science". His research is not connected to any applications. This respondent presented collaborative patterns in which he looks at emerging technologies developed by companies and analyzes them with scientific knowledge. In the same line of thought, Nobel Laureate Sydney Brenner once said "Progress in science depends on new techniques, new discoveries and new ideas, probably in that order".[8]

Researcher B.2 told us that before moving to Tohoku University, he did not have any institutional incentive to cooperate with industry. He feels, as the other

[8] As cited in McElheny (2010, p.1).

two Bohr scientists, that the influence that the institute he belongs to, The Institute for Materials Research (IMR), has a significant role on his interaction level with the industry. Indeed, the Institute has a long history of working with industry, Pr. Kotaro Honda established the Institute of Metal Research, its original name, 90 years ago in order to conduct research on steel. From the start it combined high standards of academic research and important practical contributions, such as the invention of a calorimeter, which came to be widely used in the industry. It was the IMR who, in 1916, invented the so-called K.S. magnetic steel, once considered the best in the world. Under Pr. Honda's lead, the IMR became one of the guiding forces of metal research in Japan (Bartholomew, 1989). It is currently labeled by the Ministry of Education as a Center of Excellence (COE)[9] for basic and applied research on metals and a wide range of other advanced materials. It produces high quality research while at the same time favoring cooperation with industry. Our three researchers felt the influence of the institution in facilitating and favoring relations with industry while at the same time expecting high academic standards and publication output.

The three researchers we selected had a very high publication rate by all standards: indeed the less productive had published approximately two peer-review papers a month for the last four years (see Table 4.3). Let's see now how and why they collaborate with industrial partners.

Collaboration with the industry

The first element that came along was that the respondents perceived industrial collaboration as a way to get new knowledge and solve concrete problems. Researcher B.1, who specialized in simulation and computer assisted material design, told us: "My research is inspired by emerging technologies mainly developed by companies. I analyze these technologies with a basic science perspective." He gave us the example of a collaboration he had with the Japanese company NEC. He was asked to work with them on the development of a new material for industrial application that would not contain lead, as it poses health and environmental

[9]The COE program was established in 2002 by the Ministry of Education to cultivate a competitive academic environment among Japanese universities by giving targeted support to the creation of world-standard research and education institutions.

hazards. He worked with the industry to better understand the fundamental laws of a given material by using simulation in order to design a lead-free component. In his view, he had a scientific problem to solve. He could freely work on the subject and publicize the results the way he wanted. The industry did not put any restriction on the way he should conduct his research or divulge his results, hence they did not invade the communalism of the scientific community. As a result, he published a few articles with co-authors from NEC who spent some time in his laboratory, and subsequently some papers without them. The company internalized the information and conducted research on it. However, respondent B.1 told us that he did not have any access to this further research. He has not been involved in any application using his theoretical results.

Two other researchers, B.2 and B.3, both had previous experience working in an industrial laboratory as junior scientists, respectively at IBM and Bell Laboratories. They both moved there for a period of a few years as they saw it as a positive option for their research. In the field of MSE, it is often expensive to conduct experiments, and for that reason many scientists chose to work in an industrial laboratory in order to have access to better facilities than they could have in their respective universities. Both respondents qualified their work in those laboratories as "basic research" or "pure science". The kind of work they undertook was the same as one they would have done in a university, but it exposed them to industrial methods and needs. They both believed that such experiences were an important element in the construction of a positive view of industrial research. After moving to IMR respondent B.2 and B.3 initiated many interactions with industrial scientists. Researcher B.2 told us that as a theoretical physicist by formation, he was not necessarily naturally inclined to work with industrial partners, but his extended experience in a corporate laboratory made him aware of the potential benefit of working with industrial scientists. It is interesting to note that respondent B.2 wrote his most cited paper while working at IBM laboratories.

Motivation

Asked about what were their motivations for collaboration, Bohr respondents told us that funding was not a major consideration for them as they received most of their research budget from the state or public bodies. What interested them most is obtaining some realistic problems and applications from their collaboration. Their aim is to obtain knowledge on the current state of industrial research as the field of MSE is closely connected with developments in the industrial community. Researcher B.3 told us about the need to get "seeds" from the industry to develop new theories. The notion that their research methods were different, but complementary, was also tackled. Researcher B.3 told us that: "My main motivation is definitely to get new ideas from companies. Their way of research is completely different from what we do, it brings new problems that we can tackle with our tools". In trying to solve new specific problems, the scientist creates new scientific knowledge. Additionally, the difference in time frame was also raised: whereas industry wants results comparatively sooner than their academic counterparts, a situation which creates a sense of urgency that could be conducive to an increase in productivity.

A second reason to collaborate is the development of scientific instruments, software and new materials that the scientists need for conducting research. In that case, the academic researcher interacts with the industry to develop new products that will be used for their research. As end-users, they can provide industrial with information about their needs. Researcher B1 conducts extensive collaborative research programs with industrial collaborators to develop new software and computers needed for his simulations, which are very calculus intensive. Researcher B.2 was approached by a few instrument-makers who wanted to tap into his theoretical understanding of materials; he decided to work with them as the more application-oriented members of his research team could use these instruments.

Publications as the main intended outcome

The three researchers get the majority of their funding from public sources, thus collaboration with industry is not motivated by financial considerations. All of them are involved in some contractual research agreements with companies but the income generated from these activities is quite small. In terms of commercialization initiative, they are listed as inventor on a few patents, but they are not well aware of the status of the patents. Researcher B.3 told us that since he started conducting research with industrial partners, he has been involved in some projects that led to patent applications by a company, but he basically lets the company deal with it as he is not interested by the process. In the same vein, respondent B.1 told us that during his career, he was "only involved in 10 patent applications"[10], but as he is not very interested by the application-side of his research, he lets his partner companies apply for patents as he thinks it is a way for them to protect their investments.

All together, their formal interaction with industrial partners was rather limited, but sustained through informal collaborations with industrial researchers as exemplified by their high number of papers co-authored with industrial scientists (see Table 4.3). From our interviews, we did not find evidence that UIR hindered their research in terms of secrecy, delay or by diverting them from fundamental research. It is in their view rather seen as a way to have an end-user perspective of their research, new inputs and problems to solve. In that exchange, they stick to academic publication to diffuse their results and see patenting as a necessary time-distracting makeshift to satisfy their corporate partners. In that sense, the industrial scientist who wants to collaborate with them has to internalize the values of academic scientists and participate in the publication activity.

Interpretation

What could be the first interpretation from these interviews? First, in the field of MSE, informal collaborations between Bohr type scientists and industrial researchers are quite consequent. These researchers are very productive in term of scientific publications, published their results in prominent journals, and yet interacted a lot with industrial researchers. This result is quite fundamental: it shows that in this field, academic achievers have an important part of their research conducted with industrial partners, in our case around 12-20% of the outputs are co-authored with at least one member of the industry. Far from hampering their publishing activity, we heard stories relating positive interactions. Our researchers were mainly interested in getting new ideas or problems to work on.

[10] Actually, he is listed as an inventor in 12 Japanese patents.

None of them told us that patents were of major interest, nor acting as a major impediment to their research. In terms of conflicts resulting from the collaborations, they seem to be quite small, the two actors each doing their job in relative separation, the academic providing ideas and theories, the industrialists applying them. As for patents, none of the researchers seem to be particularly interested by the question. Even if they were listed as an inventor on some as a result of their common work with the industry, they are not involved in drafting the patent, are not sure of the proceeding of the application, and are not aware of the utilization of it. Additionally, none of them reported to have scanned patent documents as part of their routine.

In Figure 4.1, we provide a graphical representation of the main results obtained in the interviews. We view the relation as sequential and with a clear distinction between the participants. First, the flow of information originates from the industry. In their collaboration with the industry, academic researchers first get new ideas, data or problems to solve from the industry. Second, they address the problem and provide some theoretical solutions to the industry. Third, the industry conducts subsequent work based on the academic researcher's work. The academic is usually not involved in this part. As for the output, they materialize mainly in terms of co-publications. The main finding in this sequence is that there is a clear distinction between the roles played by researchers from industry and academia. From the university's point of view the norms of open science are not curtailed: industrial researchers accept these norms while cooperating with the university while appropriating the results and conducting independent research for the follow-up steps.

4.4.2 Edison

> "Patent is the extreme side of originality"
> Researcher E.1

An application-prone field of research

Our three researchers work in fields where industrial applications are widespread. We shall first briefly describe their research and stress the potential applications.

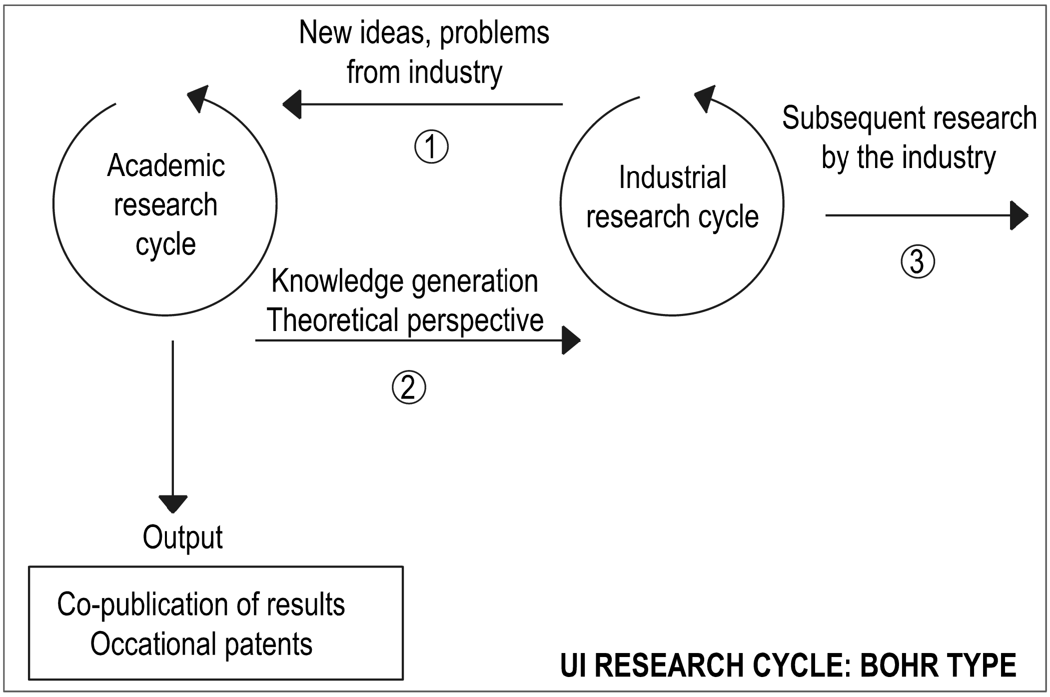

Figure 4.1: Idealized UI collaboration pattern of a Bohr type scientist

Our first researcher, E.1, has been mainly working on *copper interconnects research*; it is a multilayer, inter-conducting light structure on top of a silicon device. These "interconnects" refer to conductors through which electricity flows between various circuit elements on a semiconductor chip. Researcher E1's work is to develop new materials to improve the performance, and the reliability of these conducting layers. His research is of great use for the industry. He started conducting basic research on the layer properties, which led him to publish in 2005 a prominent paper cited on 44 occasions. Spurring co-authorship with 18 industrial researchers. According to the researcher, the reason for this interest is an overwhelming potential for the semiconductor industry to save money. Nowadays the diffusion barrier layer of semiconductors is made of Tantalum (Ta), a very expensive metal. He found a way to eliminate Tantalum by "adding a bit of manganese into copper", a much cheaper technology.

Our second respondent, E.2, works on carbon nanotubes that are cylindrical nanostructures. These molecules have properties that make them potentially useful in many applications, such as hydrogen storage, electronic devices, sensors and probes, etc. Their main interest lies in the fact that they exhibit extraordinary strength and unique electrical properties, and are efficient thermal conductors. The carbon nanotube area has brought considerable attention in both academia and industry. The exponential increase in patent filings and publications over the past few years indicates growing industrial interest that parallels academic interest (Baughman, et al., 2002). Nevertheless, it is still very difficult to manufacture them in large numbers with an adequate level of purity, indeed all known methods of synthesis of the particle result in major concentration of impurities. As such, the scientific base has to be developed to improve the fabrication process and enable applications.

Our third researcher, E.3, has been studying physical properties of liquid crystal, opto-electronic devices, high performance liquid crystal display (LCD) devices and application to the advanced display systems since the 1980s. His entire career was dedicated to the advancement of such technologies; he is one of the most renowned Japanese academics in the field, and has received various prizes as a consequence of this findings. All these researches are of great interest for the industry. Our scientists work with applications in mind, and consider the industry as an important partner to develop their ideas and prototypes.

Forms of collaborations with industry

In the field of liquid crystals, Japanese companies are at the forefront of technology, but competition is intense between them. The industry is composed mainly of set makers (ex: Sharp) and manufacturers of materials for making the displays. Surprisingly, the information shared between these two types of partners is rather limited, although it would be beneficial for all participants to collaborate, to exchange their needs and information. In order to minimize this effect, researcher E.2's team gathers information in order to gain an overall view of the advances in the industry. He has been working for a very long period of time with around 20-30 companies, all the major players of the industry in Japan. His team has monthly meetings with the companies where they discuss their common research interests. In his view, the main merit of this kind of organization is to centralize different streams of information; he can synthesize them and provide some direction of where the research is heading, pinpointing common problems. In this context, the role of the researcher is to foster cooperation between industrial players.

How do industrial and academic researches influence each other: In respondent E.2's opinion, industry and university can cooperate in the "pre-competitive" phase of research. In his laboratory, he develops basic theories with an application in mind that is tested by his industrial partners. The basic concepts are developed within his laboratory, thereafter he contacts all his partner companies to see which ones are interested by the technology. He is searching for industrial partners because the task of developing prototypes and commercializing them does not fall within the financial realm of the university. To protect their investments, companies have to apply for patents, therefore he gives priority to this channel to diffuse his research. Publications are only published *a posteriori*, after a patent application has been submitted. He does not see patents as a way to generate income; it is rather a way to foster collaboration with industrial partners.

Researcher E.1, working in the field of interconnecting layers cooperates with many industrial partners as well. One of his biggest projects with the industry took place, from 2004 to 2007, within STARC (Semiconductor Technology-Academia Research Center). STARC is a research consortium, funded by Japan's leading semiconductor manufacturers, which aims to strengthen the technological foundations of silicon semiconductors and to enhance the international competitiveness of Japan by commissioning universities to undertake basic research and/or promising joint projects with them on a sizable scale.[11] Since its creation in 1995, it has been conducting joint research with universities and the semiconductor industry to support domestic research in the field of semiconductor technology. Respondent P.1 received around $100.000 a year to work on various STARC projects. Aside from the financial rewards, he considers the prospect of having to work with industrial researchers from many companies positively. While being a member of STARC, he enjoys the visit of 3-4 researchers from the industry every three months, during which they organize seminars to discuss his results. During these

[11]For more information see http://www.starc.jp

visits respondent E.1 received feedback from industrial research and suggestions from their industrial viewpoint. This collaboration also opens the doors to use industrial research facilities to develop prototypes based on his research, which is very valuable to him as he does not have proper facilities within the university to manufacture prototypes.

Patent over publication

As the Edison researchers have applications in mind, they need to cooperate with the industry for two reasons. First, they want to have feedback from potential users of their technologies. Second, they are looking for industrial partners to develop their technologies. Researcher E.3 expresses this idea: "I need help from companies to do my research. I produce seeds and show them to companies to see if they are interested to develop them."

Edison-type scientists consider patents as an essential tool for their research. As a large part of their work is oriented towards industrial applications, they all acknowledge the need of patents to initiate collaboration. Researcher E1 told us that he was seeing "Patent [as] the extreme side of originality." According to him, publications are the consequence of a lengthy process as opposed to a patent application, which gives priority to the first applicant starting from the moment the application is completed. On top of that, you have to prove the originality of your invention. These two properties make it quite an efficient way to publicize research in the industrial sector. The aim of a publication is to make results public, therefore, according to our researchers it limits the incentives of companies that have to do subsequent work in the field. In these circumstances patents play an important role in the industries they are working with. By focusing on publications, the researchers feel that the companies they respectively collaborate with would not be protected in the perspective of follow-up.

As their research interests mainly the industry, their works tends to be lowly quoted by the academic community. As their work is directly related to applications, and as their main users are companies, their publications are not highly quoted. In their view, this can be explained by the fact that company scientists are not focusing their work on academic publications. In that sense, they see patent as an essential tool to diffuse and protect their work. Furthermore, if their patents are licensed, they can increase their research budget with the related income. However, they still consider publication as an important output of their academic work and they try, when possible, not to delay publications over a patent. However, this opposition can create some tensions and some efforts are required to conciliate the two activities. Researcher E.1 described the following in terms of how he organized his research: he makes a distinction between his patenting and publishing activities. In terms of free access to information, when students work on a project he lets students "publish in time": patenting in this case should not be detrimental to students' needs. In that case, respondent E.1 says that he is busy publishing the related patent before his students publish the findings, in order to avoid delays. In terms of secrecy, respondents acknowledge that they refrain from divulging some information that could jeopardize their patent applications and relations with industry. They are particularly weary to reveal fabrication processes of the material they work on, but are eager to divulge their scientific properties and potential usages.

Regarding money, researchers E.2 and E.3 do not think of patenting as a way to generate income. It is rather a way to initiate industrial collaborations, although E.1's view is a bit different: he generally prefers to find license partners to market his inventions to, and as such patenting is a way to generate income.

Interpretation

Figure 4.2 represents the idealized cycle of research between UI for Edison-type researchers. First, the research usually starts at the university. If there are some applications, the researcher contacts an industrial partner and collaborates with them to develop the respective technology or applications. Then, industrial scientists and academics work together to develop new technologies. In that cooperation, the norms of academic sciences are altered as the university researchers are mainly interested in applications and the desired outputs are patents, not all information is divulged. At this stage, results are divulged. This bring new research funding and market know-how to the academic researcher, who can start a new cycle of research.

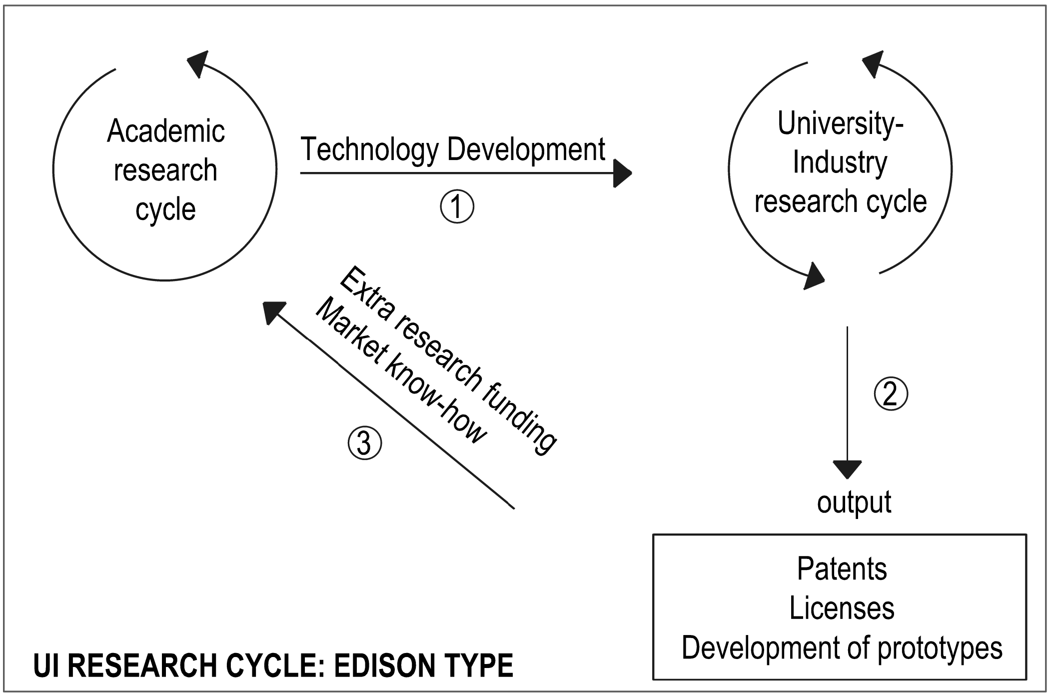

Figure 4.2: Idealized UI collaboration pattern of an Edison type scientist

4.4.3 Pasteur

> "Even if the two activities are quite different, it takes less time and effort to write a patent than a paper in *Nature* or *Science*."
> Researcher P.3

Our Pasteur-type scientists are the ones with the more complex interactions with industry, as they are engaged actively in the two communities, academic and industrial. We will therefore give a precise account of the interviews we had with them.

a. Researcher P.1

Our first researcher explores the different properties of metal alloys and investigates the phases of alloys' transformation. He qualifies his research as "pure basic research", but he is also interested in the integration of basic materials science in applications; in his view, the two aspects of the work go hand in hand. Some of his latest research projects are the following:

(1) Development of high temperature resistant copper alloys for steam engines;

(2) Development of an aluminum alloy to generate hydrogen;

(3) Development of high temperature lead-free solders for semiconductors.

For his line of inquiry, respondent P.1 feels that conducting only basic research is not enough. His research policy lays on the principles enacted by one of the founding fathers of the Department of Engineering: 1) Research first to foster world-class education; 2) Develop applications based on basic research.[12] In that respect, he thinks that high quality research with applications in mind will benefit education, social welfare and bring in additional funding to finance basic research.

The organization of his research activities can be summarized in the following way: He first conducts basic research work, and then considers if some of the findings may be applicable. In that case, he asks his students and colleagues to work on a patent application first, rather than on publications. Patents are more important in his view as a patent needs originality more than academic papers. When his team proceeds in patent applications, he contacts companies who might be interested by the application. He then directs his students to write a paper, with the potential to present it at a conference to diffuse the results. He explains the process in the following way:

> Publication takes time and discussions; it takes sometimes up to one year until it gets released. But patents can give you priority and originality, as your results will be put in place the day of application.

Table 4.4 indicates the number of publications, presentations and patents of his research team for the years 2007-8. The interesting point is that the members of his team have participated in an important number of national and international conferences. He says that, in his view, it is also a very important channel to meet industrial partners and exchange ideas with them.

As for patenting, respondent P.1 does not feel that it is detrimental to his research, however, he admits that it can delay the publication of his findings. He

[12] These are two of the three Tohoku University's ideals: "Research First", "Open Door" , and "Practice- Oriented Research and Education" .

does not usually receive money from patenting activities in terms of license. But patenting helps him foster cooperation with companies and get contractual research not only from them, but also from governmental institutions such as the Japan Science and Technology Agency (JST), as it is a criterion taken into consideration when applying for or receiving research grants. He is interested in patents primarily because it enables him to create cooperation with industrial partners, a practice which is vital for the development of his inventions. Indeed in the field of MSE it takes a very long time to move from research to commercialization: it often takes up to ten years to commercialize a product, that is why he thinks that IPRs are a needed protection to engage in such a lengthy process.

Table 4.4: Publications and communications of researcher P.1's team

	Publication	Domestic Presentation	International Presentation	Patent
2007	27 (9)	42 (28)	29 (10)	15 (8)
2008	30 (13)	34 (19)	31 (10)	9 (1)

Numbers in parenthesis represent output numbers where a student of his team was involved.

b. Researcher P.2

Our second researcher is relatively young compared to the other scientists in our sample. Still an associate professor, his team includes only three permanent researchers. He majored in crystal chemistry, and his main assistant is a physicist. The team's main topic of interest is the development of novel scintillator crystals, and related crystal growth technology, characterization and device application. Research activity in this field has been strong in the last ten years due to the growing number of applications and their demand particularly in the field of high-energy physics, medical imaging and homeland security. The team designs and synthesizes new materials from a viewpoint of crystal chemistry, and investigates their structure and physical properties. They are always carrying out their research activity considering industrial application.

As our previous researcher, his collaboration with the industry is quite sequential. He defines it in the following way:

> In most of the cases when we find a new result, we ask our industrial partner to submit a patent, and after 2-3 months we present a publication (...) Patents are rather useful for the industry; from our point of view, it is also helpful because it is a positive tool when we are applying for funds through a national project. Patents may be seen as a proof that we are really collaborating with the industry. Indeed, if the collaboration outcome with the industry only materializes in a publication, evaluation committees (for national project) may not believe that the industry is really interested by the collaboration. If the industry submits a patent, it means that they need a budget and that they are investing into the project; these conditions are valued positively.

So far, our interviewee did not see any problem with this pattern: first the industry files for a patent, then his team publishes the results in an academic journal. He sees patents as a way to signal the effectiveness of his collaboration with the industry. It is a positive element while applying for a national project. On top of that, industrial money provides extra funding for his research. Crystal growth activities are highly expensive, especially due to the price of the chemicals involved in the process. Therefore, when considering his research budgets the help of industry is essential. Furthermore, respondent P.2 believes that in his line of research, government funding goes preferably to teams that are cooperating with industry.

In terms of output, respondent P.2's team usually patents first the results and then publishes, two to three months later. According to him each patent brings a few associated publications. In the case of patents, their content is relatively broad for the scientific part, and the description of the methods and the definitions of the claims are the most important elements. For publications, in his view, you have to be very precise and logical: in that case the theoretical construction is the important element. Industry often asks him not to open the know-how part in the publication: concretely this refers to the techniques required to grow crystal. He is free to publish the chemical and physical properties of it, but not the know-how that is patented. The limits are detailed in the cooperative research contract. He believes that it is the same for his academic colleagues/competitors who work with the industry, and that the shortcomings of such relations are outnumbered by the positive points.

c. Researcher P.3

Our third researcher focuses his research on oxides; the ubiquitous oxygen-bearing compounds found in everything from granite and glass to ceramics, chalk and dust. For many years, researchers tended to shy away from using oxides in advanced applications, because they are more difficult to produce than metals and semiconductors. The situation changed in 1986 with the discovery of high-temperature superconductivity in certain oxides. However, due to the complexity of thin film growth of metal oxides, applications are still in their early stages and the way from scientific curiosity to real applications is still long. For instance, oxide thin films are roughly at the same stage of development as semiconductor thin-films were in the early 1970s (Heber, 2009). The scientific understandings are still in their infancy, which means that, in terms of applications, many problems have to be resolved before we are able to produce samples for real applications.

While asked to describe his research, respondent P.3 told us that he did not see himself as a Pasteur scientist. He envisions himself alternatively as a Bohr scientist and then as an Edison scientist. He tries to combine these two aspects of research. He does not really get demands or ideas from the industry. He conducts his basic research on materials and then looks for potential applications. He then tries to initiate contacts with companies. The most positive outcome of this sequence is that he receives feedback regarding the use of his findings, which helps him determine what industry's interests are. He is mainly funded by public money, even if he receives large sums from the industry. At the beginning of his career, when he did not have a consequent research budget, he was welcoming private money and was also consulting to raise funds for the purchase of chemicals, which is a very expensive part of the budget in his field. He has a research budget of around $1 million a year which is secured for the next 5 years. Thirty percent of it is used to purchase chemical products for his experiments, 30 percent to buy machines and 30 to hire extra staff for his team: post-docs, secretaries, and technical staffs.

Respondent P.3 usually initiates relations with industry by himself. In order to have bargaining power with the industry, he patents the applied part of his research. He does not consider that a publication in *Science* or *Nature* would give him enough negotiating power. In his view, companies want to make money and need to have a way to protect their investment. He has a few licenses generated from his patents, but the main source of collaboration comes from collaborative research contracts with the industry. If a company blocks him in terms of publication – as it happened a few times - he does not reiterate the collaboration. Companies often contact him after talks in conferences. In that case, he will accept to work with them only if it is related to his research agenda, as he does not want to dispense time on a research that is too far from his field of competence.

He does not see patents as a factor slowing down his research and related publications, and usually he publishes fairly fast after the application for a patent. In that sense, he is an enthusiast of the first-to-file system of the Japanese and European system. In terms of diffusion of knowledge, he sees the two based on the same principles but with different usages. His most cited papers are nearly all linked to a patent. In terms of knowing how to write a patent, he believes that it is a less technical document than a paper: "Even if the two activities are quite different, it takes less time and effort to write a patent than a paper in *Nature* or *Science*." They are often based on the same ideas but the purpose and techniques are very different.

d. Researcher P.4

Our forth scientist belongs to the Department of Engineering.[13] He was trained as a chemical engineer, and is currently working on the creation of new polymer structures. He manages a relatively sizable research unit. His laboratory is composed of himself, an associate professor, three assistant professors, 12 full-time researchers, 3 technicians, 5 post-doctoral students, and 4 secretaries. The laboratory he directs was created in 2002.

Since the creation of his laboratory, industrial research collaborations have played a major role in his research activity. He reckons that the research conducted in his laboratory is dual. The first line of inquiry is the quest for applications derived

[13] The study of this case was conducted in collaboration Makiko Takahashi and is treated in more depth in her doctoral thesis (Takahashi, 2010).

from new polymer structures. In order to achieve that goal, he sets up his research agenda according to company needs and polymer specifications used by the industry, what he refers to as *type 1* research. In that respect, working with industrial partners is central to his team, particularly to gain access to industrial specifications and needs. To foster collaborations he hosts many industrial researchers in his laboratory, who are usually working with him under commissioned research contracts. In the laboratory, they work together with university scientists to develop polymer that will match company specifications. In conducting experiments together, they exchange best practices and know-how. As the research is oriented to match applications needed by his industrial partners, technology transfer is smooth between his research unit and companies. The length of this kind of collaboration is relatively short-term. The academic output is rather thin compared to the intellectual property that is generated. The range of research is restrained to company needs.

However, this type of research alone would not be sustainable in his view. In order to develop new concepts and technologies he does what he calls *type 2* research. Compared to the first one, the research is more exploratory. Here, the team works on the development of new polymers. In order to achieve this goal, he is engaged in more fundamental and long-term research. Publications are the main desired outputs. In that part, there is little to no collaboration with industrial partners, but rather with external university researchers if and when the needed competences are not present within the team. He believes that, in his field of research, the combination of applied research (*type 1*) conducted together with industrial partners along with more pure academic research (*type 2*) is mutually reinforcing.

In order to gain a better understanding of the way he organizes his research, we synthesized his laboratory's research projects in Figure 4.3. We discussed with him and elaborated a schema of the different activities that were undertaken since the creation of his laboratory until 2012. In terms of scientific understanding needed for his research, he defined three interconnected research areas that he mobilizes and investigates. These areas are very fundamental in nature: his team first worked mainly on nanoparticle properties from 2002 to 2005, then moved to hybrid-particles from 2005 to 2009, and finally to conduct research on thermodynamics. His team undertakes this research based on scientific inquiry, which is why we label it as "science-oriented research". In the process, this research bears many potential applications. As a consequence he has since 2003 initiated joint research projects with industrial partners, and since 2007 his team is part of a national project regrouping 9 companies for a five-year period. The industrial partners work in collaboration with the academic team. We coin this type of research "application-oriented" in figure 4.3. His team alternates between the two types of research: science-driven and application-driven. They are cross-fertilizing.

In terms of output, the team has been producing around 15-20 publications a year since 2002. As for patents, respondent P.4 was listed on few corporate patents as an inventor, and three were applied together with the technology licensing organization of the University. As a result, a start-up company has spun off from his unit to exploit results originating from the laboratory. The team is also collaborating with companies to pursue the industrial production of some particles designed by its members. What we can see from the organization of the work is that our scientist seeks to develop new academic theories and concepts together with practical applications in mind. IP plays an important role in collaborating with industrial partners, but in order to generate the IP, fundamental research published in academic journals is needed.

4.5 Discussion

The exposition of the case revealed in our view many salient features and important points that one must take into consideration when comparing it with the literature on UIR. First, our method of selection may have been too categorical to help evaluate differences between the researchers. Indeed, we categorized them by considering just two dimensions, patents and publications, which generated different patterns of conducting science. Indeed the patterns of collaborations with industry, the motivations, the way it affects their research agenda, and more generally their research strategies, revealed to be quite different for each category.

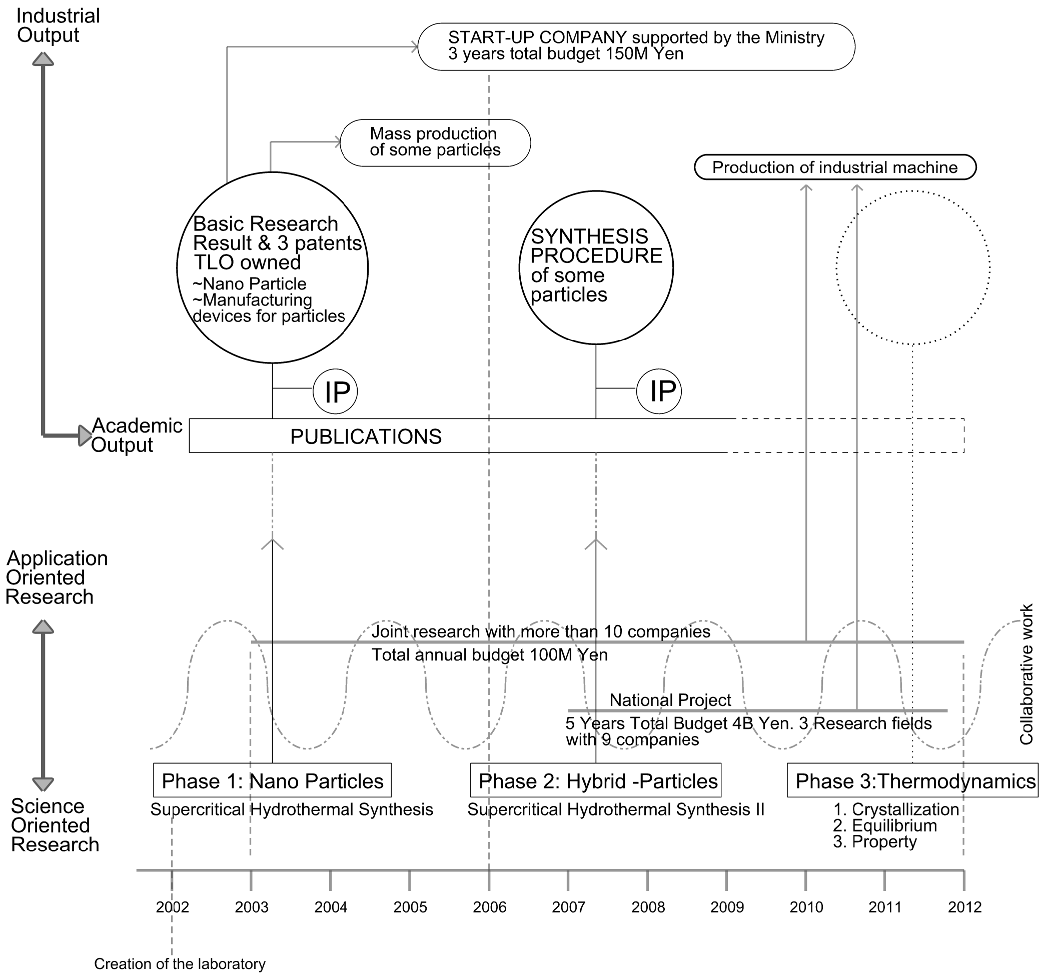

Figure 4.3: Synthesis of UI collaboration activities of a Pasteur type scientist, the case of P.4

In this section, we first stress the “two-way” type of relationship that seems to prevail in the MSE field as opposed to more unidirectional relationship in the field of life sciences. We then move to the academic interpretation regarding the use of patents, in their view it is rather a tool to enter cooperation with industrial scientists than a way to transfer technologies *per se*. Next, we try to evaluate the level of relevance of collaborating with industry for our three types of researchers. Finally, we stress an unresolved research question.

4.5.1 A two-way approach: the importance of building a relationship

An element that clearly emerged from our analysis is that UIR in the field of MSE and among the scientists we interviewed are characterized by a "two-way" approach. As industry is the main locus for the production of technology, academics working in the field of MSE need access to industry to provide them not just with research materials but also with information about where to direct their research. Similarly, in the broader field of engineering, Perkman and Walsh (2009) showed that basic projects with industry could lead to immediate scientific output: they give the example of firms who contributed to academic projects by providing prototype machines and "real world" data from their testing laboratories, a dynamic reminiscent of that encountered by Bohr scientists. With regards to applied projects, Perkman and Walsh noticed that these projects involve high degrees of interactivity, which in turn generate learning opportunities. This attention towards fostering relationships with firms was found in of Owen-Smith and Powell (2001, p. 107):

> [P]hysical scientists believe patents provide leverage at multiple levels, within the university, in relationships with firms, and in federal grant competitions. Life scientists are more concerned with patents as a means to attract investments in their research from firms and venture capitalists. The life-scientists' image is less one of building a relationship than of capital infusion.

When life scientists focus more on the proprietary benefits of patents, physical and engineering ones tend to emphasize the relational benefits of patents as a facilitator of industrial collaborations. We think this element is linked to the different opportunities that are entailed in the respective knowledge bases of the discipline. Specifically, applications in the pharmaceutical industry are based on codified, analytical knowledge. Indeed, advances in molecular biology and genetic engineering are offering the opportunity to extend the applicability of a scientific method of drug research. Industry scientists can increasingly make use of fundamental knowledge about human metabolism and the action of drugs. In that process, it becomes necessary for pharmaceutical companies to tap into the depository of academic knowledge. In turn, academic scientists have many opportunities to transfer their analytical knowledge in quite a straightforward, arms-length relationship. This fact is perspicaciously deciphered by Gambardella (1995) in his account of innovation activities in the US pharmaceutical industry. One of his arguments is that the generation of new drugs depends largely on the activities that occur at the beginning of the R&D process. This observation led Gambardella to state that in the pharmaceutical industry: "Early research stages play a more meaningful role than in other industries, and they are the most creative steps of the drug innovative cycle" (ibid., p.14). In an environment of increasing scientific intensity and usage by pharmaceutical companies, there are opportunities for rent-seeking agents in the university to monetize their research results. A striking example of this tendency is the case of Craig Venter, a controversial American neurobiologist and former researcher at the National Institute for Health (NIH), USA. He became famous for competing against the federally funded Human Genome Project in sequencing the human genome. With the company he founded, Celera, he claimed in 1998 that he would complete the sequence of the human genome four years before the worldwide, non-profit project deadline of 2005. This entailed a very big response by academic community who participated in the public project, as they feared that Venter was not completely committed to place the genome in the public domain. Their fear was in part valid, Venter's motive to engage in such an inquiry was that he thought he could earn money in the process. His business plan was the following; his company would make money by selling data-access subscriptions to the information they would create, rather than developing new drugs from their discovery. The product sold by his company would not be just "a highly accurate, ordered sequence that spans more than 99.9% of the human genome," Venter said. "The goal is to develop the definitive resource of genomic and associated medical information".[14]

Our point here is that some properties of the life sciences academic research, which we refer to as their analytical properties, make it easier for some scientists to cash-in on their knowledge through direct involvement in or with in the industry. This is especially the case in the biotechnology industry, where academic

[14] As cited in McElheny (2010, p. 140-1).

researchers navigate easily between both worlds.

What seems to us different from the MSE experience is that the relationship is more unidirectional, from university to industry. In the pharmaceutical field, university discoveries are often located at the beginning of the research process; their output, for instance the synthesis of a new compound, can be patented and easily integrated in the innovation process of a pharmaceutical firm. Indeed, the drug innovation is composed of fairly standardized steps, which are mainly designed by regulatory authorities (e.g., see Gambardella, 1995 for more details on the process). After the initial synthesis, which can be done in an university department, the job of conducting laboratory research as well as animal and clinical testing does not generally rely on the academics, but is rather the task of the pharmaceutical corporate laboratories. On the other hand, in the field of MSE, interactions are needed to evaluate the usage and application of new materials. In that process, information sharing is needed to generate final products; the process is iterative by nature, and academics can be integrated in the innovation process from the conception of material, to their improvement, all the way to the construction of prototypes and commercialization. This interactive and long-term horizon of research is well illustrated by the research conducted by respondent P.4 and its schematic representation (Figure 4.3). P.4 has many industrial partners spanning over a long period of time. In that sense, we believe that there is a need for intense communication between academia and industry in the field, which has the unintended effect of diverting the use of patents from their original role: promoting innovation and technology transfer. We address this element in the next section.

4.5.2 Research organization and scientific ethos: patent as a bargaining tool

The norm of communalism seems to hold across our three categories of researchers. It requires scientists to produce knowledge that can be evaluated by the community. In principle, an experiment should be verifiable and reproducible. When published in a peer-review journal the scientific community assesses if the work can be validated within the established knowledge framework. In that respect, publication is a central part of the evaluation and validation of an academic scientist's findings. One possible fear is that collaboration with the industry will alter this norm. Our guess from the interviews is that while it does not alter this norm, it adds a dimension to it. Clearly, the commercialization dimension is incorporated in the "credit cycle" of scientists. As Latour and Woolgar (1986) remarked, scientists build their stock of capital through investments that will secure their credibility as scientists; this credibility is in turn measured in terms of trust and reliability that others have recognized in them. Being at the interface of science and industry, the academics we interviewed need to build up a stock of capital in both the industrial and academic world. This entails antagonist demands, which can lead to damageable outcomes such as delays in the publication process, increased secrecy or twisting of the research agenda. Even if we have stressed these elements previously, it is not on these points that we intend to structure our analysis.

Instead, what we want to pinpoint here is how they play this patenting card to help secure their credibility among members of the industrial community and towards the members of the academic community. The patent system, in a straightforward interpretation, is supposed to facilitate the diffusion of technological information by granting a monopoly right as an incentive for the applicant to innovate in exchange for information disclosure of the discovery. But the patenting activity of the scientists we interviewed did not seem to fit this pattern. Actual products or process that could be used by consumers were rarely a major theme of the discussion we had with them, nor were the quests for capital infusion. For them, patenting is a way to materialize their links with the industry, more than a vehicle for technology transfer. Patents are conceived as playing two major roles. First, they play a signaling task in their endeavor to attract industrial funding. Their involvement in such an activity demonstrates sensitivity to industrial needs in the face of potential partners. It also shows researchers who are competent not only to produce scientific knowledge, but also to secure it for commercial use. Second, for many scientists it is a necessary payoff given to the industrial sponsor of their research.

Packer and Webster's (1996) work analyzes the emergence of the patenting culture in British universities, and shows that scientists use patents to maintain and further their position in the credibility cycle by building a bridge with the industrial community. One of the scientists they interviewed summarized it in the following way: "It really is what one is looking at the patent for. It's advertising, it's window dressing, it's to allow you to go to the next stage, to raise funding, to allow you to indicate seriousness in what you are doing."(ibid., p. 444). As such, everything sounds right and does not seem to create any problem: patents and industrial collaborations are just another tool to increase the scientist's position in the credibility cycle. But as Packer and Webster argue, patents are not like publications, they do not serve as a source of information or as a mean of cementing academic networks.

As it was argued by many of our interviewees, patenting does not just involve different rules from academic publishing. It is a different game altogether. Writing papers and building an audience for one's ideas involves enrolling other academics in a collective project; patenting has more to do with controlling others. This tendency is illustrated in a well documented article written by Myers (1995) who describes the tenuous route of two academic researchers writing their first patent applications from their laboratory research. The story is informing as it reveals the antagonistic norms and logics of the two exercises, the main differences are exposed in Table 4.5. Myers notably remarks that while academic articles need support from prior texts to build up their case, patents must not be too closely linked to prior documents as it could threaten the essential novelty aspect. When you write a paper you want to cite all the previous literature to reduce the potential for criticism by referees or other negative reactions by reader. The task is to

Table 4.5: Differences in article and patent activities

Article	Patent
Claims for Novelty are based on assumptions of specialist readers	Claims for novelty are based on knowledge of a 'person skilled in the art'
Links to other texts strengthen the case	Links to other texts weaken the case
The story relates a specific claim to a line of larger significance	The story demarcates the general claim on the basis of specific practice
The article is a signpost on a route	The patent demarcates a territory

Source: Myers (1995)

build up on previous knowledge and show how your contribution is adding to the collective task. On the contrary, in a patent such detailed references to the previous art might lead to the work being seen as obvious and not patentable. Indeed, references should not be too close to the previously disclosed invention since that may jeopardize the patent claim. In that sense, Myers sees patenting as demarcating a territory, whereas publications act as signposts on a route.

We first noticed that, in our setting, patenting is mainly apprehended as a means to foster industrial collaboration by increasing a scientist's credibility in the industrial sphere. This activity, though, has a cost. Even if we agree that the secrecy entailed by such an activity is limited to its minimum, it still generates a behavior that emphasizes the demarcation of a territory at the expense of a more open-ended activity. The question then is until which point is the industrial involvement appropriate for an academic researcher.

4.5.3 Level of relevance

Perkmann and Walsh (2009) analyzed 55 research projects involving university and industrial researchers, in the engineering department of a UK university. The analysis of these projects enabled them to generate a four-fold typology of research projects. The four categories are the following: knowledge generation, idea testing, technology development, and problem solving. One of their main findings is that these different types of projects differ with respect to their "appliedness", or as they noticed "their proximity to market" (ibid., p. 1037). While knowledge generation projects made only very generic reference to market-ready products or services, at the other end of the scale, problem-solving projects addressed issues relating to products, processes or services that were close to market. In their analysis, Perkmann and Walsh took into account two levels, the effect of collaborations on publishing and the learning opportunities resulting from cooperation. They summarize their finding in the following way:

> While more basic projects are more likely to generate academic output, they also offer fewer cross-boundary learning opportunities. As such projects are often led and carried out by academics and address topics less directly relevant to industry, partners tend to be less involved and hence interactive learn-

> ing effects are reduced. In contrast, although the attractiveness of applied projects is hampered by secrecy and complementarity problems, they offer more learning opportunities during via highly interdependent interaction with industry. (ibid., p. 1055)

We chose to focus on researchers and not projects, though we can use some of these finding to organize our case. Bohr scientists, in their relation to industry, were nearly always involved in knowledge generation projects. These scientists mainly find new ideas or theoretical problems to solve from the industry. In this process, there is a relatively low level of integration and interdependence between the partners. The interactions are rather informal and materialize mainly in co-publications. When comparing the number of companies they had formal collaboration agreements with, with the number of partners with whom they worked on publications, we found that the later is higher (Table 4.3). This fact hints towards informal collaborations between the scientists of the two communities. In their relation with the industry, projects are rather academic and the industrial partner is rather seen as a sponsor or provider of ideas rather than an active project participant.

At the other end of the spectrum, Edison scientists are interested in finding partners to develop their ideas and discoveries. They actively take part in project development activities and consulting. They are mainly involved with projects that show high degree of interdependence. For instance, researcher E.1 was part of research consortia (STARC) with many companies and interacted with them on many instances to develop new technologies and products; researcher E.2 has been involved for a long period of time in a large formal and informal network of collaboration with numerous companies. In the process, their research strategy is defined by their corporate partners and the technological opportunities that appear during their interactions with corporate partners. While patenting is part of their day-to-day research, publications are a by-product of it. However, they still advise their students to focus on publishing. In order to launch an academic career, the credit derived from publication is the most important element in finding a position.

The third group, Pasteur scientists, is very interesting because it encompasses scientists that seem to be able to cater to the needs of both industry and academia. They manage to have a close interaction with industrial scientists while at the same time maintaining the lead in designing their research projects. Their close collaboration with industry facilitates interactive learning. Using the typology of Perkman and Walsh (2009), we determined that Pasteur scientists were mainly in idea testing, a goal they achieve through their relationship with the industry. Many of their projects with the industry were inspired by the desire to investigate ideas with a possible commercial interest. Being interested in the applications, but not willing to invest too much time in their realization, they preferred to outsource the development to cooperating firms. The projects they told us about were mainly built on concepts and technologies developed by academics that were then traded through patents, licenses, and research contracts to firms who could pursue tentative exploration of their application potential.

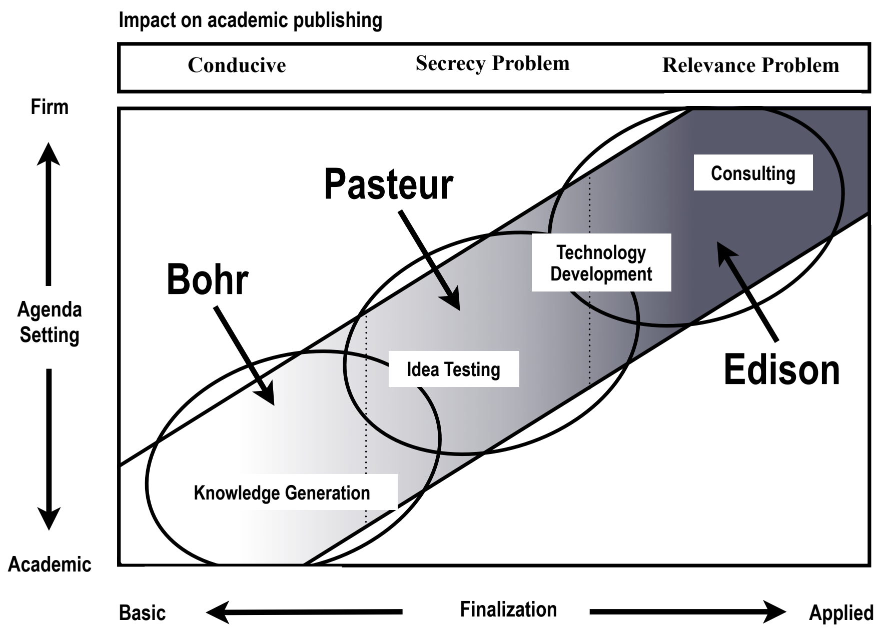

Figure 4.4: Agenda setting and impact on academic publishing

Figure 4.4 summarizes our results by taking into consideration two dimensions: the level of appliedness of the research, in line with Stoke's classification, and the responsibility in the research agenda (company or the academic). Using this pattern, three ways of conducting research are clearly emerging. Bohr scientists keep their research agenda in their own hands, as we have summarized in Figure 4.1. They receive data and problems that they investigate using their own research methodology from the industrial side. In the process, their main goal is to generate new knowledge. The collaboration, in their view, is conducive to new research areas. Their main output is publication that they co-author with industrial partners. Working with industrial scientists, they increase their research productivity and are very attached to wide and unrestricted diffusions of their research.

On the other hand, Edison scientists want to develop technologies related to their research area, and in the process engage into technology development activities and consulting with industry. Their main outputs are patents. They argue that only focusing on academic publications would not be sufficient to induce cooperation with industrial partners. In parallel, they recognize that their academic publications are not necessarily well-quoted and/or published in academic journals with wide audience or "impact factor". Holding patents is not so much a means of enhancing the credibility of scientists in their research, but a means to tie into companies and put limits as to where others could use a specific piece of knowledge. In that respect, patents may lead the scientific community to question the relevance of their work. As within the scientists' credibility cycle, patents do not serve as sources of information or as a means of cementing academic networks. They are not a way to enroll other academic actors.

In the middle, Pasteur scientists, by focusing their work on testing the ideas that emerge from the research conducted in their laboratories, manage to keep their work at a certain balance. They all told us that they wanted to keep the agenda setting and not relinquish it to their industrial partners. They also show a certain ambivalence in the organization of their research team. As respondent P.4 told us, he views his work as a dual organization, between what he called a *type 1* research, in close cooperation with industry, and *type 2* research which is more explorative and isolate from industrial partners.

4.5.4 The importance of teamwork: a path to explore

All this being said, there is a need to be cautious on one point not often mentioned in the literature. It may be obvious, but all the researchers we have met had a pretty large research team that enabled them to sustain a large productivity and engage in various simultaneous projects. Table 4.4 summarizes the sizes of the laboratories of our selected researchers.

All the teams have more than ten members, the bigger ones composed of more than thirty scientists. The teams incorporate permanent researchers, students and researchers coming from the industry. The biggest teams are found within the Pasteur group. Of course the division of labor is not vertical and hierarchical; rather, the members of the team have significant autonomy, but all work under the direction of the lead researchers to solve common problems.

Table 4.6: Personnel in the laboratories: 2009

Category	Permanent researchers		Post-graduate and post-doctoral students		Industrial researchers	
	Min	Max	Min	Max	Min	Max
Bohr	3	6	8	20	0	2
Edison	3	6	10	20	0	5
Pasteur	3	8	8	30	2	5

This point stresses the need to have a collective approach when tackling researcher productivity. Our lead researchers are only entailed with such productivity because of the supporting work and talent of their team. When asked about the subject more precisely, they all stress the importance of teamwork within their laboratories. All of our respondents exercise a very strong influence on their team. They were listed as writers in nearly all the publications of the laboratory and as inventors on the majority of the patent applications. They play an important influence on the permanent researchers and students of their laboratories. In Chapter 2, we have shown that at the departmental level, one echelon above the laboratory, the colleagues' level of publications and patents had a positive and significative impact on researcher productivity. To put it succinctly, you are influenced by the research strategy and productivity of your colleagues. As such, the inclination of

Edison scientists to file for patents certainly influences their colleagues and students to do the same. The question then is how does this influence the work and career of their colleagues? The question has not been addressed here. But we believe that it is a question of high interest. Indeed, all the researchers we interviewed are by all standards very productive, yet in different ways; the nature of their influence on their colleagues remains unanswered.

On the industrial side, this dimension has been addressed on many occasions. The question of the impact of collaborating with "star scientists" has been tackled by Lynne Zucker an her colleagues in a series of work, centered on the field of life sciences, which demonstrates that *star scientists*, defined as the top-producing genetic sequence discoverers, had major impacts on biotechnology firms entry in the market or subsequent firm success. Baba et al. (2009) established that "Pasteur scientists", academics with a high number of publications and patents, increased their partner firms' R&D productivity, measured by the number of registered patents. Furukawa and Goto (2006), studying the research productivity of researchers active in the 10 highest R&D spending firms in the Japanese electronic industry, found that what they called "core scientists", researchers with the highest number of publications and citations, had a strong positive impact on promoting co-authors' patent applications. With their large number of papers in academic journals, they play a major role as boundary-spanners bringing knowledge from academia and thereafter, stimulating the patenting productivity of their colleagues who can apply the findings.

In that respect, it would be interesting to devise an experiment to determine whether productive scientists in academia emulate the work of their peers, especially the Edison type. Indeed, as we have demonstrated in the field of MSE, input from industry is needed and sought by academic researchers. But do Edison type scientists, with their high share of patent applications, have the same role as "core scientists" in the industry as knowledge brokers, bringing in industrial knowledge and perspective and subsequently boosting the research productivity of their colleagues? In order to gain an idea on the matter, we examined the publications of the co-authors that were permanent researchers at Tohoku University during the period 2004-8 (Table 4.5).[15] The results are based on a very small sample and as such have to be taken with caution. Nevertheless, we found that researchers E.2 and E.3 worked with academics with a productivity superior to the mean of our baseline population, 12.1, E1 with one below and one above the mean. We cannot conclude from this data whether they exercise a positive influence on their colleagues' productivity or not, but they at least seem to collaborate with colleagues who exhibit a relatively high productivity. What influence do such academic scientists play on their co-authors, if any, is a question that has yet to be tackled. An answer to this question could mitigate or exacerbate the relevance problem we have identified earlier. This is certainly a question that needs further research.

Table 4.7: Number of publication: Edison scientist's co-authors

Co-author's number of publications (2004-08)	E.1	E.2	E.3	
1	13	26	53	32 (4)
2	9	25	41	13 (5)
3			33	10 (6)

4.6 Conclusion

The aim of this chapter was to enrich our understanding of the influence that industrial collaborations have on university researchers. Our strategy was to design a case study centered on very prolific researchers in the field of MSE. We chose this discipline, as it appears to be a fertile field of research for studying UIR. This strategy had the merit to depart from studies in the crowded field of life sciences. We interviewed 10 academic researchers that we divided into three categories according to their level of publication and patents.

The main results of the analysis are the following. First, we found that the research organization with industrial partners was radically different among our

[15]More precisely, we made a list of all the co-authors that were listed in the Edison scientists' publications during the period 2004-08. We then compared this list with the name we had retrieved for our analysis in the Chapter 2. We found 2 matches for E.1 and E.2 and 6 matches for E.6.

three groups of researchers. Bohr scientists were mainly cooperating informally with industrial researchers and were seeking knowledge and problems to solve from their industrial counterparts. Indeed, even if their research was mainly centered on the basic imperative, the characteristics of the field of MSE created the need to have an end-user perspective even for the most theoretical scientists. At the other end of the spectrum, Edison scientists had their agenda largely dictated by commercialization objectives leading to a close integration of their research with industrial scientists. They favor patents over publications and are actively engaged in commercialization activities. However, we found that in many instances patents are not conceived by academics as a way to transfer technology as such, but rather as a bargaining tool to signal a researcher capability to work with the industry and therefore gain credibility in the industrial world. This fact is particularly prevalent in the Pasteur group, which manages to combine high levels of both academic and commercial output. This element can be put into perspective with some of the results found in Chapter 3. Indeed, we found that researchers who are conducting both basic and applied research are more likely to be positive towards patenting, as they do not see this activity as conflicting with their publication output. The results drawn from the interviews are similar; Pasteur scientists keep their hands on the research agenda and find ways to combine both theoretical and applied works.

Third, compared with the experiences of UIR in the life sciences sector, the dynamics in MSE seem to differ. From our analysis, a “two-way” approach seems to emerge from UIR. Our interviewees gave the impression of being engaged in bilateral knowledge sharing. The synthetic part of the knowledge embedded in the MSE, and more generally in the engineering disciplines, necessitate close cooperation between the partners involved in the innovation process to develop a new material. From the synthesis of a new material, to the conceptualization of its uses to the development of prototypes and fabrication, many steps can involve academic and industrial partners. In that process, there is a cross fertilization of the expertise, academics cooperating with industrials and focusing rather on fostering cooperation and learning than on capital infusion as the majority of their research is financed by public bodies. One could argue, as Kneller does (2007), that this emphasis on cooperation, rather than on licenses and creation of new academic ventures, is a phenomenon common in the Japanese academic system. This argument has some weight and is supported by recurrent evidence, but we still think that the opportunities offered by the field are more prone to cooperative strategies than to venture businesses. Finally, we addressed in this chapter the question of relevance in cooperating extensively with industrial partners, as is the case for Edison scientists. As we have shown in Chapter 2, the two activities seem to complement each other in many instances, but there is certainly a plateau after which the activities are cannibalizing one another. Whether one could define limits and set guidelines for successful cooperation, is a difficult question. Perhaps, the answer is lying somewhere else, in the creation of new ways to communicate the results, an adaptation by the academics in response to increasing commercialization pressures and opportunities. That is something we shall examine in the next chapter.

In the next chapter, we will conceptualize the notion of hybridity of research practices and norms between academia and industry. We will argue that, in academic fields where the commercialization imperative and opportunities are present, academic researchers are trying to combine antagonist demands in an original way.

CHAPTER 5

TOWARD A HYBRIDIZATION OF THE SYSTEM

> *Traditional boundaries between university and industrial science, and between basic and applied research, are disappearing. As a result, science and society are invading each other's domain, requiring a rethinking of previous responsibilities. [...] For most of the twentieth century, universities, government research establishments and industrial laboratories have therefore operated relatively independently, developing their own research practices and modes of behaviour. Recently, however, this relative institutional impermeability has gradually become more porous. Privatization policies, for example, have moved many government research establishments into the market place. [...] Meanwhile the expansion of higher education has been accompanied by a culture of accountability that has impacted on both teaching and research. In research, many academics have had to accept objective-driven research programmes, whereas research funding agencies have been increasingly transformed from primarily responsive institutions, responsible for maintaining basic science in the universities, into instruments for attaining national technological, economic and social priorities through the funding of research projects and programmes.*
>
> — Gibbons (1999)

5.1 Introduction

The aim of this chapter is to conceptualize the notion of hybridity of research practices and norms between academia and industry. Specifically, we analyze the emerging evidence of a trend, partly induced by new government policies and partly by substantive development in science itself, which has encouraged the co-evolution of previously separated communities. As argued by Gibbons (1999) in the introductory quote the norms and practices of research in university and industrial laboratories have converged. There are still differences between universities and industry, but these do not impact on their scientific research results. In his view, scientific expertise is more and more distributed among many agents and institutions. It cannot emerge on one specific site or within a small group of researchers. Rather, scientific expertise must arise by bringing together many "knowledge dimensions" originating from universities, industries, government and the general public.

We agree with the fact that research practices and norms of the scientific and technological communities are co-evolving, influencing each other. This idea has emerged and has been reinforced with evidence throughout this thesis. We wish to provide here a concrete example illustrating such a tendency. We show that academic scientists are finding ways to adapt their research to the contrasting demands of these two communities. We draw on the concept of patent-publication pair developed by Murray (2002) to illustrate this tendency. The findings derived from this approach suggest that scientists are adapting the sources they draw upon, and the way they communicate their results according to their audience. This phenomenon of adaptation appears to be quite pervasive. On top of that, we show that the citing network of patent-paper pairs within the technological and scientific communities seem to be distinct.

This chapter is organized as follows. First, we define the concept of hybridity, which is a response to the opportunities that arose from the creation and diffusion of commercial knowledge, in order to apprehend the changing nature of norms and practices in academia (5.2). We then propose a way to measure this tendency: the patent-paper pair (5.3). Using this indicator, we analyze in Section 5.4 the pairs produced by two researchers.

5.2 The concept of hybridity

We wish to address here the fact that, under some circumstances, university and industrial science are becoming more alike. Starting from this statement three observations can be immediately made. First, we observe that an institutionalization of entrepreneurial norms in universities is clearly emerging. We have seen in Chapter 2 that, in Japan, many policies were implemented in recent years to facilitate the cooperation between the university and the industry, to ease the technology transfer of university inventions. These policies had particularly potent effects among the youngest cohort of faculty members. As such, we suggest that entrepreneurial norms are diffusing in the case of Tohoku university, and more generally in many research intensive universities (Kleinman and Vallas, 2001; Slaughter and Leslie, 1997).

The second observation we make is that the attitude towards these entrepreneurial norms is not spread evenly among faculty members. It spans from accommodation to resistance, and from fitness to unsuitability. In Chapter 4, we have described different attitudes towards commercialization activities using three idealized types of researchers: Pasteur, Bohr and Edison.[1] Even if Bohr-type scientists had experiences of collaborations with industrial partners, they were strongly attached to the Mertonian way of conducting research, while Edison and Pasteur-type scientists were willing to embrace a more entrepreneurial way of conducting science: patenting, research contracts with industry, co-decisions of research projects with industrial partners, etc.

Another example of this ambivalence can be found in Shinn and Lamy's (2006) study, which found that some academic entrepreneurs perfectly combined commerce and science, while others focused on commerce at the expense of science. They carefully studied a group of 41 French academics who had established a firm.[2] Their results suggest that certain categories of academic entrepreneurs display greater facilities than others to ally the generation and application of com-

[1] More details about this classification can be found in Chapter 4, Section 4.3.

[2] An extended version of the interviews can be read in Lamy's doctoral thesis (Lamy, 2005, chap. 7).

mercial knowledge with academic imperatives. The authors evaluate the adequacy of commercial and industrial incentives using two dimensions: the degree of university-enterprise synergy and the level of academic autonomy. The most successful group of scientists is what they referred to as "Janus" (the name of the Roman god who looks in opposing directions), a group that manages to combine simultaneously a great autonomy and a strong synergy with industrial partners. They provide the following narrative to exemplify their claim:

> Janus states that the material resources and experience in managing personnel derived from the firm provide a stimulant to networking and publication. One person declared that the quality control protocol he developed in his firm extended his international renown and proved useful in his laboratory work. The growth in publication frequently stems from university–enterprise co-publications, or directly from applied technology articles. (ibid., p. 1474)

This statement portrays a story close to the one we encountered for Pasteur-type scientists in the previous chapter, even though we did not use the same dimensions to create our categories. This view, however, reinforces our findings by stressing the existence of different levels of ease when collaborating with industry and coping with antagonist demands.

The third observation we make is that accommodating the logics about applicability and commercial objectives in academic research leads to institutional hybridity, and leads universities and industry to come closer together in some areas of research. This notion of a hybrid system was developed by Owen-Smith (2003), who shows that the success of academic institutions increasingly rests on their ability to deploy hybrid strategies for commercializing their scientific research and to use such assets to support academic pursuits. Success in academic and commercial standards have become integrated in such a way that achievement in one realm is dependent upon success in the other. Similar conclusions can be spotted in the works of Toke (2010) who found "institutional convergence" in the conduct of joint projects between academics and SME researchers in Denmark. These joint projects seem to be constructed on shared cultural platforms based on tacit understanding. While a majority of the researchers recognized that cultural differences once constituted a barrier to collaboration, they are now experiencing a convergence of their working norms and conducts. Vallas and Kleinmann (2008), as well, conclude from interviews with members of the academic and commercial biotechnology communities that a process of convergence is underway in which the codes and practices of industry are infiltrating the academy.

All the evidence that has been enumerated so far has been chosen to highlight the many contributions that claim the existence of a convergence between academia and industry. In our setting, we decide to rely on the term *hybridity* of practices and norms. We define the term in the following way: in a position in which academic and commercial dimensions are both present, an industrial or academic scientist is influenced by both norms and practices of the two entities. In that process, new arrangements emerge to cope with often contrasting demands. What we are interested in here is how, on the academic side, faculty members engaged in commercial activities manage to combine both demands. As Etzkowitz et al. (2000) put it:

> [T]he key issue is how far it is possible for academic scientists to combine Mertonian and entrepreneurial values in an ethos of entrepreneurial science in which the extension and capitalization of knowledge are made compatible. There are continuing tensions between mobilizing knowledge as a public good and maintaining the incentives to do this, and controlling its value as a private good. (Etzkowitz et al., 2000, p. 326)

The tension between the public and private good characteristics of knowledge in academic science is an element of investigation that is at the center of this thesis. This element was approached with different angles throughout the thesis. What we want to stress in this chapter is that instead of opposing these two elements, one way to approach the problem is to use the concept of hybridity, or how the academics adapt themselves to these pressures. We have demonstrated in the previous chapter that the scientists we interviewed were using patents in a peculiar way: in their view, they were a means to maintain and to further their position in the credibility cycle, rather than solely a way to transfer technology. In many instances, these scientists used patents to initiate and maintain connections with outside institutions such as companies. Here, we wish to go a step further and show another adaptation mechanism, which we detected from the results of the two previous chapters.

In summary, we draw on the concept of hybridity to apprehend the changing nature of norms and practices in academia that result from the creation and diffusion of commercial knowledge. Instead of focusing on antagonist elements, we focus on subtitle changes that originated from collaborations and common objectives between academia and industry. Now, we need a tangible measure of this concept. This is what we present in the next section: patent-paper pairs.

5.3 A way to measure hybridity of practices

We enter this discussion through an analysis of an artifact that enables us to apprehend how features of academia and industry come to intermingle. Fionna Murray (2002), in her paper, wanted to find a way to capture the traces of interconnections between the scientific and technical community. She reached this goal by using the concept of *patent-paper pairs.* Her method is based on the premise that whenever scientific and technical constructs become intertwined, the same idea is often diffused in both a patent and a paper, thus forming a patent-paper pair. As she puts it, these two documents:

> form a natural experiment because they transcribe the same idea and yet the texts are distinct – a paper describes experimental results, while a patent defines utility and makes claims on inventiveness. Such pairs are, therefore, paradoxical: they make a contribution to distinctive institutions and trajectories and yet they represent inscriptions of one underlying idea. (ibid., p. 1392)

Such pairs constitute an experiment to analyze situations when science and technology overlap. They exemplify the intertwined nature of scientific and technical ideas and communities. A single pair provides scope for the exploration of two citation networks. This element has the advantage of giving us a clear picture of who is using the new idea. It also provides a basis for the comparison of networks of scientific and technical progress and their overlaps. Citation analysis has long been used to measure knowledge spillovers across organizations. Patent-to-patent citations indicate spillovers of technological knowledge, while patent-to-science citations indicate spillovers from scientific fields (Narin, et al., 1997). This measure is, however, intermediated by patent examiners who are involved in the process of citation (Alcacer and Gittelman, 2006). In the scientific literature, citations are used to measure importance and impact and provide some mapping of scientific progress.

Analyzing the citation patterns as well as the persons and institutions involved in an important patent-paper pair in biomedical science, Murray emphasized two important results. First, she showed that scientific and technical progress arises mainly in two distinctive networks: one consists in the community of science, while the other one is a mix between the institutions of science and technology. Second, she found very few traces of spillover through co-publication or citation. Instead, she found that the two communities were interacting through a range of ties centered on key scientists. These scientists engage in the practices of both technical and scientific communities. They build ties among communities and are actively engaged in promoting the development, in both communities, of their initial idea.

Murray and her collaborators have conducted many subsequent studies using patent-publication pairs as an artifact. They show that this practice is quite widespread in biology. For instance, out of a population of 4,270 human gene patents (covering almost 20% of 23,688 known human genes), they could identify 1,279 human gene patent-paper pairs. These pairs were distinguished by the shared disclosure of a gene sequence in the "gene paper" and in the claims of the "gene patent" (Huang and Murray, 2008; Jensen and Murray, 2005). They also found evidence that patent-paper pairs are an important phenomenon in high quality research in the life sciences. According to them, nearly 50 percent of articles published in *Nature biotechnology*, a high-quality scientific publication, are associated with a pair (Murray and Stern, 2007). Altogether, the production of dual-use knowledge seems to be increasingly central in scientific research in the life sciences. It represents a noteworthy example of the emphasis put on intellectual property within academia, and how academics respond to new incentives. A growing number of ideas once placed solely in the public domain are now additionally embedded within the patent system. Murray and Stern (2008) are quite clear on that matter:

> The rise of such patent-paper pairs is emblematic of the life sciences community's expanding production of knowledge that is simultaneously of scientific and commercial interest. Patent-paper pairs are also the focal point for many of the specific instances in which life science patenting has roiled the life sciences knowledge community. (ibid., p. 19)

Murray and her collaborators have spotted the phenomenon in the life sciences. Our interest is to find whether or not patent-publication pairs are present in another fields. Based on data from the interviews in Chapter 4, we investigate this question in the field of Materials Science and Engineering (MSE). First, we can state that there are some historical examples of such pairs in the field of MSE. For instance, William Shockley undertook transistor related experiments in January 1948 as described in his Bell Labs lab notebook (No. 20455, p.128-32, January 1948). Less than six months later, in June 1948, he filed for a US patent on the solid-state transistor (US Patent 2,569,347 issued September 25, 1951). In 1949, he published the theory underlying the transistor invention. In our case, we took the opportunity of having access to scientists who showed signs of being involved, with more or less depth, in both the technical and scientific communities to investigate the issue of patent-publication pair.

5.4 Examples from materials science academics

5.4.1 Selection of cases

In order to examine whether patent-paper pairs were prevalent in our context, we devised one question in the survey sent to the Tohoku academic inventors to evaluate the scope of the phenomenon.[3] We subsequently asked all the researchers we interviewed in the Chapter 4 whether or not they used this method to publicize their results.

First, we wanted to have a way to evaluate the dual pressures that an academic might face while working with an industrial partner. In that respect, we asked via

[3] The reader can refer to Chapter 3 for more details on the survey.

survey a question centered on the channel of diffusion chosen to present the results of a research conducted in collaboration with an industrial partner. We chose this question, instead of one explicitly centered on patent-paper pairs, as we were not sure if all the researchers would grasp correctly the concept.

The results give us some valuable indications (Table 5.1). First, approximately a third of the faculty members think that companies give priority to patenting over publication, and approximately 10% of them favor either patent or publication as a way to present their results in the case of a collaboration with the industry. The results are quite similar whether we consider the entire population of respondents or only the engineering part of the sample. Second, we find trace of an adaptation by the academics to the characteristics of the results when choosing the channel to use. 44% of the respondents, and 51% in the case of engineering said that they decided, with their partner, on the best way to present their research findings. This element gives some weight to the vision of a hybrid posture by academics. Depending on the results and the needs of their partners, they decide in which community, technical or scientific, they want to embed their results. In many cases, however, the demands of the two communities may be antagonists. For 44% of the respondents, conflicting situations arise: the company wants to publish and the academics aspire to publish. In that case, negotiations are needed to satisfy both partners. This last element can be interpreted in the light of patent-paper pairs: facing contrasting demands, an academic may decide to use both patent and paper to publish results based on a common idea. One potential agreement would be to use both channels in an ordinate manner, first patent and then publish, to please both partners needs. All the Pasteur scientists we interviewed in Chapter 4 described this mechanism to us, albeit in different terms.

In the process of our interviews, we explained to all the researchers the concept of patent-paper pairs. We subsequently asked them if they used this artifact to diffuse their results. Their responses are one of the important findings of this chapter. Succinctly, all the Pasteur and Edison scientists used, in many instances, both patents and papers to communicate the results underlying one idea. Therefore, the phenomenon does not seem to be limited to the life sciences, but rather, it seems to pertain to other fields of research, especially when scientists are pursing both academic and technological ventures.

In the next section, we centered our analysis on two cases: one from an Edison scientist (researcher E.1) and a Pasteur scientist (researcher P.3). We discussed extensively with these two researchers about instances of patent-paper pairs. The first case enables us to show the different contents of the two documents, while the second stresses the relative ubiquity of this dual communication of results.

Table 5.1: Communication of research resulting from a collaboration with an industrial partner

How do your scientific colleagues perceive your patenting activity? (Only one possible answer)	%	%
In general, how do you present the results of your research collaboration with an industrial partner (multiple choices)	All sample	Engineering
On the company side, they give priority to patent	36%	31%
On the company side, they give priority to publication	3%	4%
On your side, you favor patent	14%	12%
On your side, you favor publication	10%	7%
You and the company decide depending on the characteristics of the results	44%	51%
The company wants to patent, you want to publish: You negotiate an arrangement with the company	44%	45%
Other	3%	2%

Note: based on 154 responses.

Table 5.2: Basic data: focal paper and patent

	Focal patent	Focal paper
Date of submission	2004, 27th February	2005, 7th March
Date of publication	2005, 3rd February	2005, 22nd July
On your side, you favor patents	12	0
On your side, you favor patents	0	30

Note: All citations are current as of January 2010.

5.4.2 Difference of contents

We discussed with Researcher E.1 about the concept of patent-publication pairs. Concluding the discussion we had with him, he told us two important elements that are summarized in the following sentence: "Patent writing technique is completely different from publication. The audiences are very different as well". Subsequently, he provided us with documents on one pair, which in his view characterized his statement. This pair is the result of a work financed by the Semiconductor Technology Academic Research Center (STARC). STARC was established in December 1995 thanks to the investments of Japan's leading semiconductor suppliers. Since its creation, STARC has been conducting joint research with universities and the semiconductor industry to support domestic research in the field of semiconductor technology. The patent and paper were published (granted) in 2005.

Table 5.2 gives basic citations statistics. The first element that can be noticed is that, in terms of citations, there is no overlapping: the patent is only cited in patent documents, and the paper in other publications. We come back to this issue in the next section. The second element we consider is the striking difference of content and style between the two documents. Some key elements of the paper and patent are presented in table 5.3 and 5.4 respectively. By displaying this information, we want to highlight the difference in contents and methodology between of these two documents. The documents are slightly technical, but should not be too difficult to read for an attentive reader.

Researcher E.1 gave us information on one of his discoveries in the field of semiconductor research, which led to a pair. In short, he developed a new ultra-thin diffusion barrier in manganese (Mg).[4] A semiconductor includes an interlevel insulating film disposed on a semiconductor substrate. Since the barrier layer has a poor electrical conductivity, its thickness should be reduced as much as possible while maintaining a good diffusion barrier property and a good adhesion strength with the neighboring layers. The problem is that the barrier layer formation has been increasingly difficult as the technology is reducing the size requirement of the

[4] A barrier layer is used in integrated circuits to chemically isolate semiconductors from soft metal interconnects, while maintaining an electrical connection between them.

layers. Our scientist proposes new methods to create "ultrathin" diffusion barrier layers.

In the concise paper (3 pages) he is very academic in style. He states the problem: there is a need to create new techniques to make a thinner barrier layer in semiconductors. He then states previous strategies of research and then proposes his alternative strategy. This part is followed by a presentation of the experimental results. He concludes by showing how his method can generate a thin interface layer (Table 5.3). The paper displays four figures and focuses more on the properties of the sample created rather than on the fabrication process.

The patent document, by contrast, is very detailed on the fabrication process and the applications of it. As said in the patent document "*The present invention relates to a semiconductor device including an interconnection*, which has an interconnection main layer *Cu (copper) as the main component* (i.e., by 50% or more) [...] The present invention also relates to a *semiconductor device manufacturing method for forming such an interconnection* by a barrier self-formation process"(Table 5.4). The document is very detailed: it contains 14 drawing sheets and 21 pages of explanations about the manufacturing of the invention. It was drafted with the help of a patent lawyer.

We could refer to the argument of Myers (1995) who followed the drafting of the first patents written by a biologist and medical academic researchers. According to his analysis, patent and papers are texts that work in different arenas. While our work does not have the depth of his fine-grained analysis, it allows us to give similar conclusions. On a similar idea, to comply with the demands of two publics, a scientist can write two completely different texts that are addressed to two distinctive arenas. In a situation, where academic and commercialization dimensions are both present, our scientist is using norms and practices of both communities.

5.4.3 Important trend or epiphenomenon?

As we already mentioned, all our Pasteur scientists have diffused some of their discoveries in a patent-paper pair framework. As their work is embedded in the two communities, and follows two different logics (quest for fundamental under-

Table 5.3: Structure of paper

1. State the problematic of the research Copper (Cu) metallization has been used as an interconnect material for advanced semiconductor devices. A typical interconnect structure is composed of Cu/Ta/TaN/SiO2 . The double layers of Ta/TaN are called a barrier layer as a single entity and are necessary to prevent interdiffusion between Cu and Si atoms. Since the barrier layer has a poor electrical conductivity, its thickness should be reduced as much as possible while maintaining a good diffusion barrier property and a good adhesion strength with neighboring layers. However, the barrier layer formation has become increasingly difficult as the technology node is reduced from 90 to 65 and to 45 nm. An alternative to the conventional barrier process is a "self-forming" barrier process. This process involves with the deposition of a Cu alloy thin film directly on SiO2…
2. Previous paths of research Previous researchers investigated this possibility, using a strong oxide former, such as Mg and Al, as an alloying element in Cu…
3. Solution proposed In the present work, we chose Mn as an alloying element because of the following favorable points over Mg and Al…
4. Present the experimental work Experiments were performed as follows…
5. Summarize the results The present results showed that Mn atoms in the Cu–Mn alloy film diffuse to the surface and the interface to form oxide. The interface oxide layer has an amorphous structure that is considered to be a favorable structure as a diffusion barrier layer. The thickness of this interface layer is uniform and is only 3-4 nm in thickness.

Note: elements in italics were added to highlight the structure of the document.

Table 5.4: Structure of patent

BACKGROUND OF THE INVENTION
The present invention relates to a semiconductor device including an interconnection, which has an interconnection main layer Cu (copper) as the main component (i.e. , by 50% or more)[. . .] The present invention also relates to a semiconductor device manufacturing method for forming such an interconnection by a barrier self-formation process. Particularly, the present invention relates to a semiconductor device and the manufacturing method
DETAILED DESCRIPTION OF THE INVENTION
According to the following embodiments of the present invention, a barrier film for preventing Cu diffusion is formed by means of self alignment between an interconnection layer containing Cu as the main component (i.e. , by 50% or more) and an interlevel insulating film This barrier film contains a compound of a predetermined metal element α with a component element of the interlevel insulating film. The predetermined metal element α may be comprise at least one element selected from the group consisting of Mn, Nb, Zr, Cr, V, Y, Tc and Re, and preferably comprise Mn.

standing and consideration for use), it is likely that, in their routine, they use this hybrid form. We addressed this question by discussing with researcher P.3. We scanned with him his most cited papers and queried whether any of them were linked with a patent.

For time and space reasons (he had authored more than 750 papers), we had to find a way to select the most significant papers among his numerous publications: we decided to choose his 15th most cited papers. We opted for the most cited papers, as we wanted to see whether scientific excellence could be combined with technological proneness. We used citations to measure the quality of a publication based on evidence from the sociological and scientometric literatures, which has long time articulated the importance of citations (Crane, 1972; Hagstrom, 1965). The result are the following. Out of the 15 publications, seven of them were published using a patent-pair pair framework. This first element gives us some indications about the nature of a productive Pasteur-type researcher's work. More than half of his most cited papers were published in pair with a patent. The results are illustrated in Figure 5.1. The papers with their number of citations, ranking, and the year they were published are on the left side of the figure. For instance, "6. *Science* (1998) - 497" is the 6th most cited paper, it was published in *Science* in 1998 and has been cited 497 times prior to January 2010. This paper pairs up with a patent applied for in 1994, which was never cited.

We can notice from the figure several elements. First, there are different patterns: one paper can lead to several patent applications; conversely, one idea can be diffused in several papers and one patent. Second, we see that the numbers of citations to patents is much smaller than the number of citations to publications. Citations to patents have a different utility than citations to publications. In the latter citations are a form of recognition of knowledge use within the scientific community. Links to other texts usually strengthen the paper. In the case of patent citations, patent law incorporates an enforceable obligation to cite prior patents when an innovator builds on prior works. While articles need support from prior texts, patent must not be too closely linked to prior texts. Scientists, when writing papers, try to present their hypothesis as flowing naturally from earlier work.

However, to be patentable one must avoid the naturally-flowing writing style of presenting pervious work as doing so might endanger the validity of the patent.

With the exception of the first patent, which has been cited 39 times, the other patents are cited once at most. In all these cases, the patents are cited by a firm. Finally, in terms of patent citation to papers, out of the 15 papers, 11 are cited in patent documents, each being cited in average 7.1 times. This fact shows the use by the technical community of scientific findings, as patent-to-science citations indicate spillovers from scientific fields. The papers are highly cited (a way to measure their use by the scientific community) and are cited in patents (a way to measure their use by the technical community).

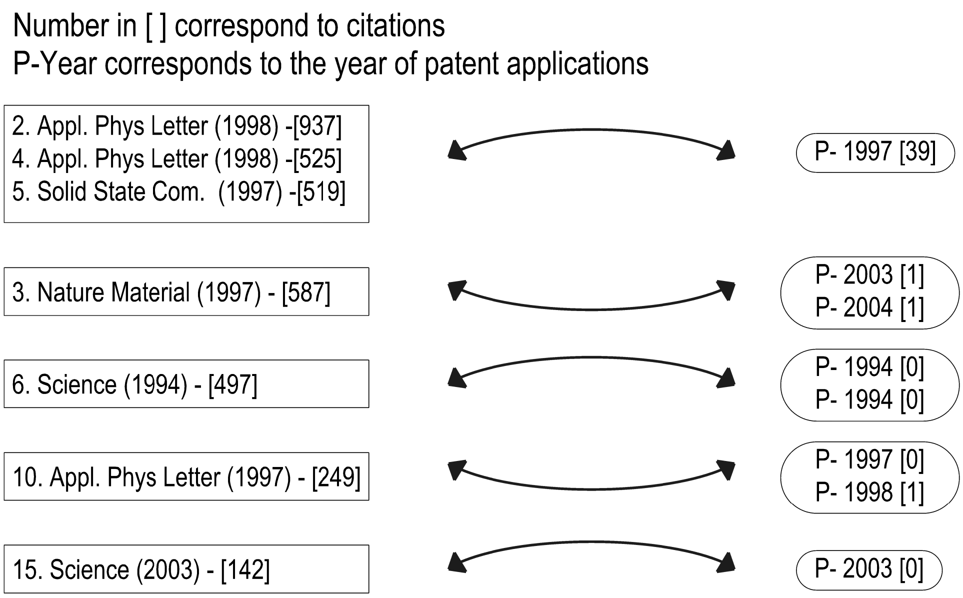

Figure 5.1: Patent-Publication pair among the 15th most cited papers

5.4.4 Empirical analysis: one patent-paper pair

We now turn our attention to the first pair. We selected it for our analysis as it exhibits the highest number of citations to the focal patent. In this section, we want to examine on what foundations these papers are built and who is in fact using them. Basic statistics in terms of citations of the focal patent and papers are presented in Table 5.5. The scientific network of users is extensive, with each paper being cited more than 500 times. In contrast, the patents network is smaller with 39 citations - considerably high for a patent. This situation is common. Branstetter (2000) for instance, with the unit of analysis of the University of California, found that citations to academic papers far exceed those to academic patents.

5.4.5 Difference of contents

Table 5.5: Basic data: focal papers and patent

	Focal patent	Focal papers		
		1^{st}	2^{nd}	3^{rd}
Date applied / published	1997 7^{th} March	1997 6^{th} August	1998 11^{th} May	1998 22^{th} June
Number of citations in papers	0	542	575	956
Number of citations in patents	39	0	13	16

Looking at the references presented in the two types of documents, we found completely different sources. The two texts are established on completely different corpuses of knowledge. The scientific work is built on scientific papers exclusively. It cites 46 references. In contrast, the patent cites only patent documents (Table 5.6). In terms of lifespan of these citations, the patent references are more recent in average than those of the papers. These elements suggest that at the time of the patent there was limited technological literature relevant to draw on. Even if the idea is common to the patent and papers, the knowledge and related literature is different. In fact it mobilizes distinctive sources with no overlap in terms of references. The scientific and technological knowledge bases are separated. This is our first finding, the two texts draw on completely different sources.

Second, we now move to the network of citation and their temporal dynamics, starting with the latter. The two networks show quite distinctive temporal patterns. The scientific network grew steadily until 2006 when it reached a peak. Subsequent citation levels have remained high. The start was slow. It then grew

Table 5.6: References to papers and patents

		Number of references	Common references	Focal Average age of references (time from publication of references to patent–paper pair publication)
	1	23 papers		10 years
Papers	2	22 papers	*46*	13 years
	3	14 papers		14 years
Patent		10 patents		7 years

at a cumulative speed. The patent network, by contrast, peaks earlier, in 2004, and then collapses (Figures 5.2 and 5.3). In that sense, the usage by the technical community of the patent document seems to be more limited and circumscribed to a short period of time. Patents correspond to the response towards a technical problem. Opportunities, and necessities, to cite previous works are more limited than in the case of a paper. This exemplifies Myers' (1995) claim. Paper are a signpost on the route where others build on, while patents serve to demarcate a territory and are therefore of use to smaller communities, for shorter periods of time.

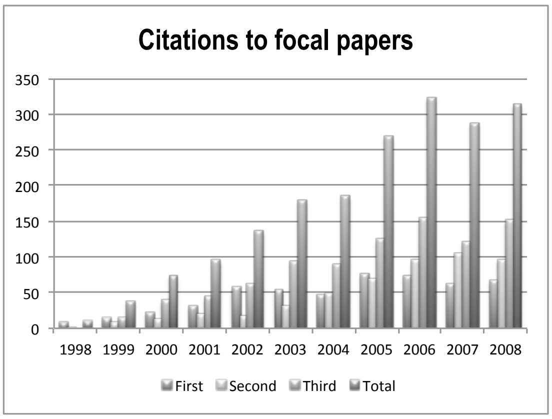

Figure 5.2: Citation to focal papers

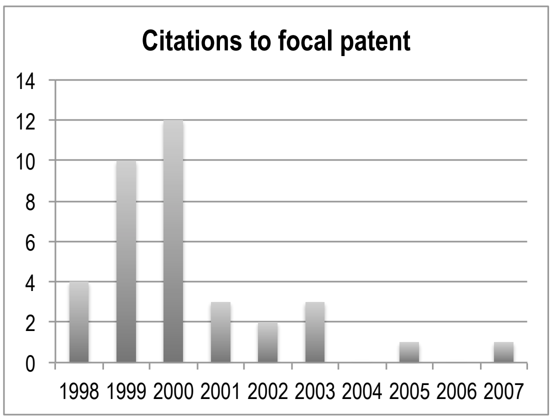

Figure 5.3: Citation to focal patent

The patent and papers are distinct in terms of reference to prior knowledge. They present, as well, different citation dynamics. The patent is mainly cited right after its publication, while papers experience a constant increase of their citations through time. The remaining question is to see how the scientific and technical communities are using these two texts. Figure 5.4 displays the institutions that cited the focal papers and patent. We made a distinction between institutions from the scientific community (mainly universities), which are on the left side of the figure, and institutions from the technical community (firms), which are on the right side of the figure.

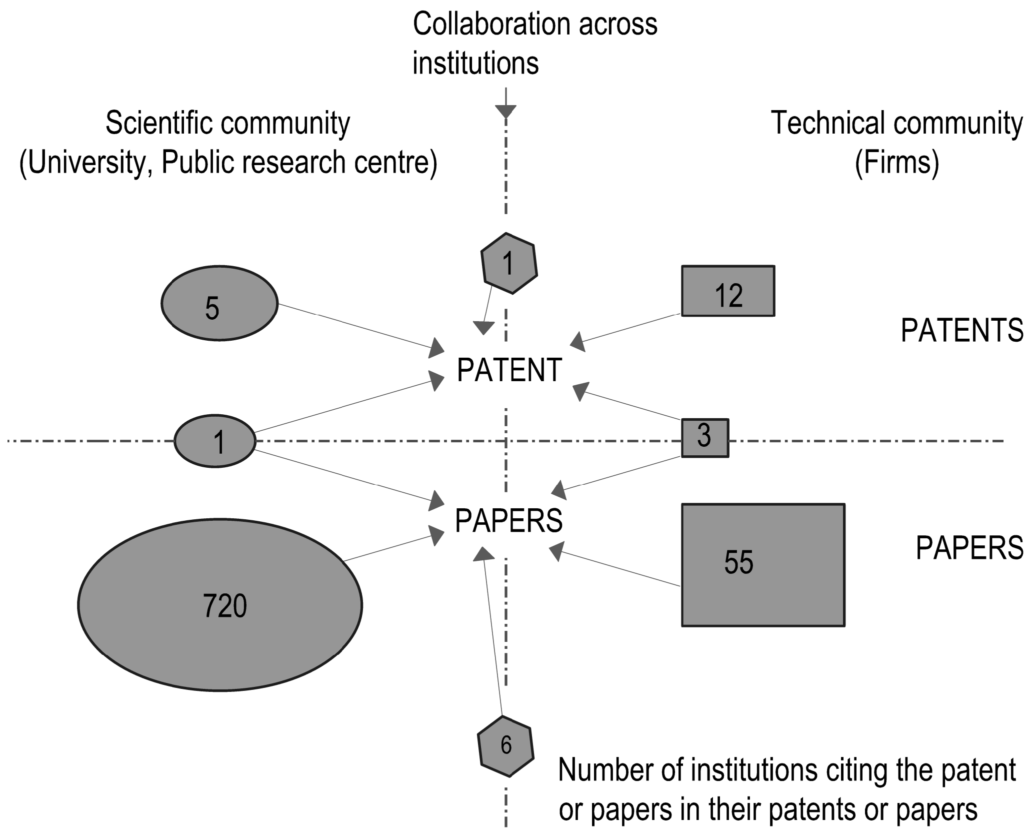

Figure 5.4: Institutional overlap of scientific and technological networks

We can make several remarks on the figure. The first element we notice is that there is no clear distinction emerging from the demarcation between the scientific and technical communities. The proportion of scientific institutions citing the papers is higher than the proportion of firms citing these papers. Conversely, the proportion of firms citing the focal patent is higher. Many scientific institutions (university, public research organizations) cite the focal patent. In parallel, a high number of firms, 55, cite the papers. As such, we can postulate that some scientific teams are building on technical work, while technical teams are using scientific results for their research: the borders are porous. These results are in line with the ones of Murray: academics are participating in the creation of intellectual property and companies publish.

Co-publication and co-patenting across networks is relatively small. In terms of co-authorship, there are only 6 cases of collaborations across institutions citing the papers. In 4 out of 6 of these cases, the main researcher was involved in the process. Hence, the main scientist plays an important role in bridging the gaps between institutions. Moreover, only one pair of company-scientific institutions cite the focal patent. These elements can be interpreted by the fact that there exists distinctive scientific and technological networks. The knowledge embedded by the patent-paper pair is used by both communities but in a separate way. This result is in line with the one of Murray, who summarizes her results in the following way:

> I have shown that scientific and technical progress arises in two distinctive networks – one predominantly the community of science and the other more mixed between the institutions of science and technology. Furthermore, there are few traces of the traditional measures of spillovers and co-evolution, e.g. cross-citation and co-publication. I find instead that these two communities are co-mingled through a range of ties centered on key scientists. (ibid., p. 1401)

5.5 Conclusion

> The challenge should be then to shift university research from a situation in which technology transfer and commercialization are seen as by-products to a situation in which these functions acquire a new higher status: that of joint product. We derive the definition of these concepts from accounting: joint products are two products that are simultaneously yielded from one shared cost and they have comparably high (sales) value. We can apply these terms to think about basic research and technological applications, substituting "perceived value to the academic professor" for sales value. Foray and Lissoni (2010)

In this chapter we focus on two intertwined concepts. First, we postulate that facing different incentives, from the scientific and technological communities, some academics have been adapting their research practices to be able to evolve within the two communities. We call this process hybridity. This process is found in many instances in the literature, and in the data we gathered throughout the thesis. Academics are using more and more patents as part of their research repertoire. But they use them with a twist. Patens are viewed as a way to foster collaborations with companies and to increase their reputation in the technological world, rather than a means to protect and transfer their inventions.

The second element of this chapter found a way to evaluate and measure this tendency. For that matter, we used the concept developed by Murray (2002): patent-paper pairs. This concept is based on the premise that one idea can be used in two documents, patent and paper. We adapted this concept to our research setting: highly productive researchers in the field of materials science. We have shown that this practice appears to be widespread and frequent among our sample. Second, we have shown that even if the idea was common, the two documents were based on completely different sources, had different citation timeframes and were cited relatively independently by the technical and scientific communities. Foray and Lissoni (2010), in the conclusion of their chapter on university research and public-private interaction, written in the Handbook of the Economics of Innovation, talk about the notion of joint-product. In their view, technology transfer activities initiated by academics should move from the state of being a by-product to a joint product. The difference being that in the latter "two products" are simultaneously yielded from one shared cost. In their view academic and commercial incentives have to be aligned to favor a smooth integration of these two imperatives. Indeed, throughout this chapter, we have shown that prolific academic researchers, of Pasteur and Edison type, were already part of a joint product economy as they were using both the scientific and technologic channels to diffuse their findings.

In our view, we have demonstrated the advantage of using a new type of indicator to measure how academics are adapting themselves to the needs of two research communities. We have also enlarged previous findings by Murray and her colleagues by showing that the use of patent-paper pairs was not limited to the life sciences. We think that there is a need to go further into these directions, and study new indicators and research fields, to investigate how norms and practices of the academic community are evolving as a result of technological considerations and industrial contacts.

CONCLUSION

> *A shift in emphasis of university research toward more extensive connections with the needs of civilian industry can benefit industry and the university if it is done in the right way. That way, in our view, is to respect the division of labor between universities and industry that has grown up with the development of the engineering discipline and applied sciences, rather than one that attempts to draw universities deeply into a world in which decisions need to be made with respect to commercial criteria. There is no reason to believe that universities will function well in such an environment, and good reason to believe that such an environment will do damage to the legitimate functions of universities. On the other hand, binding university research closer to industry, while respecting the condition that research be "basic" in the sense of aiming for understanding rather than short-run practical payoff, can be an enduring benefit of both.*
>
> — Rosenberg and Nelson (1994)

Rosenberg and Nelson's (1994) seminal paper starts with the following sentence: "Over the last decade, debate over the role of American universities in fostering technical advance has intensified". As this sentence shows, the kind of problematic addressed by this thesis is not new, yet it is still of relevance today. The original trade-off posited by the authors more than 15 years ago is still vivid in a contemporaneous context. On the one side, universities are asked to play a larger and more direct role in assisting industry. On the other side, these developments have the possible unintended effect of destabilizing the integrity of academic research. Understanding the scope, consequence, and magnitude of this trade-off is at the center of the vast literature addressed in this thesis.

The essence of the trade-off is quite simple to grasp, yet it can be analyzed with many perspectives. One can investigate the national system of innovation to see how universities are contributing to the innovative output of the system. One can observe how the university adapts itself to its new missions of technological transfer and fostering innovation. In that line of inquiry many works are studying the role of technology license offices (TLO) and the phenomenon of academic spin-offs. Finally, one can look at the various strategies elaborated by academic researchers in response to industrial considerations. This last approach is the focus of our energy.

This choice was motivated by our belief that it is one of the least investigated aspects of the problematic faced by universities in their mission of promoting economic progress. The introduction of a third mission - mainly technology transfer and commercialization activities - to universities creates new opportunities and challenges for the academics. The traditional CUDOS of academic research is under reconfiguration. Of course, the changes are not forthcoming, but rather induce new sets of circumstances and incentive structures. By focusing on the microeconomic level we aimed to understand how and under which conditions academics adapt their research practices. This approach not only has the advantage of accessing the vast information available on input and output of individual researchers, it also serves to increase our understanding of the Japanese case, a context which has seen profound changes in terms of its university system in the last decade. Setting our focus on the individual level gave us the ability to monitor precisely the effects of institutional changes on individual researchers. This is important, as academics are relatively independent workers, free to select their research projects and methods with considerable autonomy. We were interested in investigating how their agendas were adapted to this new situation, leading us to one of the central arguments of this thesis: the structure of academic work is changing in response to incentives and opportunities offered by an increasing interaction with industrial science. As the title of the thesis heralds, academics researchers are at a crossroads. In our view, the path they are prone to follow is dictated by micro-level considerations. We addressed this issue by raising three substantial and related questions. First, do academics manage to combine the traditional Mertonian way of conducting science with their new missions, technology transfer and commercialization objectives? Second, does this tendency have similar effects among the different disciplines and type of researchers? Finally, how do academics manage these new rules of the game?

The answer to the first question is generally yes, as shown by both quantitative and qualitative evidence. Chronologically in the thesis, we have documented the policy-push directed toward an intensification of university-industry relationships that occurred recently in Japan. As a result, the numbers of patents and contractual research agreements have increased rapidly. However, this increase did not originate from scratch. Particularly, before the Incorporation of national universities the majority of IP rights were transferred informally to industrial partners. This practice has changed since then as universities are managing a larger share of the IPs originating within their walls. This increasing use of formal IP rights made vivid the needs for an answer to the following question: What is the influence of patenting, which we use as a proxy for industrial enterprises, on publishing activities, a proxy for academic endeavors? The answer to this question was at the core of our econometric exercises. As a result, we found that patenting and publishing were complementary in our two experimental settings. First, within a large dataset comprising the majority of the faculty members of the engineering and science departments at Tohoku University, and second, in a smaller sample of commercially inclined scientists. In both cases, the two activities showed signs of complementarities. Although in one of our models, using stock rather than flow measures, we found a nonlinear relationship between these two variables, the two activities reinforcing each other until a certain threshold and thereafter going in the opposite direction. Another interesting result concerned the influence of a researcher's age on his/her propensity to patent: the youngest cohort of researchers is the most active in patenting their results. This may indicate the influence of policy changes: the younger researchers are more prone to embracing patenting as one element of their daily research, because their social environment publicizes the activity as a routine activity that is part of their duties.

Nevertheless, the level of complementarity depends on many factors. For instance, the increase reliance on academic patenting is perceived differently by researchers who subscribe to a traditional, Mertonian approach to research, and researchers who take a more applied, commercially oriented approach to research. Quite instinctively, the former are skeptic about the changes, while the latter, especially the ones who mix applied and basic consideration in their work, are more lenient, if not supportive of the changes. To give more weight to this insight, we decided to use and adapt the classification imagined by Stokes (1997) who describes three idealized type of researchers which correspond to type of research conducted by the eponym of their classification. As a result, we found that research organizations with industrial partners were radically different among these three groups of researchers. "Bohr" scientists were cooperating informally with industrial researchers and were seeking knowledge and problems to solve from their industrial counterparts. At the other end of the spectrum, "Edison" scientists had their agenda largely dictated by commercialization objectives leading to a close integration of their research with industrial scientists. They favor patents over publications and are actively engaged in commercialization activities. Finally the "Pasteur" group, which manages to combine high levels of both academic and commercial output, seem to be the ones more at ease with the contrasting demands of the two communities. Indeed, we found that researchers who are conducting both basic and applied research are more likely to be positive towards patenting, as they do not see this activity conflicting with their publication output. In that way, "Pasteur" scientists manage to keep their hands on the research agenda and find ways to combine both theoretical and applied works.

The answer to the final question is quite interesting. In few words, we have portrayed evidence of the creation of a hybrid structure in the way researchers diffuse their research. We found that in many instances patents are not conceived by academics as a way to transfer technology as such, but rather as a bargaining tool to signal a researcher capability to work with the industry and therefore gain credibility in the industrial world. This element made itself obvious when conducting interviews with productive researchers. They were, above all, looking for recognition from both the industrial and academic community as way to pursue their research. If cooperating with the industry, patenting the research results, or delaying the publication of results were needed to attain this goal, they posited no objection to these practices. Norms and practices of conducting academic science at the crossroads of commercialization objectives are evolving. "Pasteur" and "Edison" type scientists, scientist with subjects of interests to the industry, are using both scientific and technological channels to diffuse their findings. However, as we moved forward throughout the thesis, it became clear that in order to approach our subject under favorable conditions, there was a need for a differentiated approach: the effects and scope of the change are not the same in materials science and theoretical physics, between "Pasteur" and "Bohr" scientists, members of elite and local universities, and so on. As David argues in the conclusion of his paper on the open science arrangement, there is a need for a carefully balanced approach to the subject:

> Wise policy-making in this critically sensitive area [infrastructure of public science] must pay especial heed to the complex and contingent histories of the organizations of public science and so respect the potential fragility of the peculiar institutional matrix within which modern research evolved and has flourished. (David, 1998, p. 20)

While the norms of openness of the scientific community are persistent to changes - even if we see the apparition of a hybrid system, combining elements of academic and industrial sciences practices - the system is nevertheless vulnerable to inconsiderate changes. More knowledge is still needed to apprehend all the implications of the current policies favoring a third mission for universities and academics, meaning a collaboration with industry. No one can predict tomorrow's outcomes. However, by having a better understanding of individual behaviors, we can increase our comprehension of the organization of public science. This thesis was a first step towards a better comprehension of the determinants influencing the academic research agenda at the crossroads of industrial science. More work is still needed. First, the empirical elements of this thesis are centered on one research university, there is a need to enlarge the picture to other Japanese universities (private and public, elite and regional) to see if the results we came across are generalizable to a wider population. Second, we have shown that the norms and practices of the academic community are evolving in response to new incentives related to technology transfer activities and IPR issues; we proposed evidence that the academic actors are not passive in the process, as they are actively designing new hybrid strategies to adapt to a new environment where collaborating with the industry is advocated. This last element, the adaptive nature of research practices, is worth exploring, as the innovative mission of the university is pushed forward, but the consequences on the research practices of this movement are still to be evaluated. Finally, we have argued that UIR differ according to scientific disciplines. Our reading of the literature has shown that a lot of attention has been given to the life science disciplines together with a penchant for generalization of the results regarding this field to the entire spectrum of research. By documenting an example centered on materials science and engineering, we have provided indications that some results regarding the influence of UIR on academic scientists differ from the life science setting. Certainly, further research is needed in that area to uncover the differences related to the nature of the knowledge created when dealing with UIR.

The endless cycle of idea and action,
Endless invention, endless experiment,
Brings knowledge of motion, but not of stillness ;

— T. S. Eliot

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APPENDIX A

TOHOKU UNIVERSITY

With the aims of enhancing its international recognition and status, Tohoku University created a Logo in April 2005. The pattern of the logo was inspired by the *Hagi*, better known as the Bush Clover. This plant is one of the traditional symbol for Sendai.

Figure A.1: Tohoku University's Logo

- ***Location***

Tohoku University is a Japanese national university based in Sendai, Japan. Sendai is located approximately 300 kilometers (180 miles) north of Tokyo on the Pacific coast of Honshu (the largest of Japan's four major islands). Sendai lies in the center of the Tohoku Region (northeast), one of the seven major regions in Japan. It is the largest city of the Region. It takes about 1 hour and 40 minutes to reach Sendai from Tokyo on the Tohoku Bullet Train (Tohoku Shinkansen).

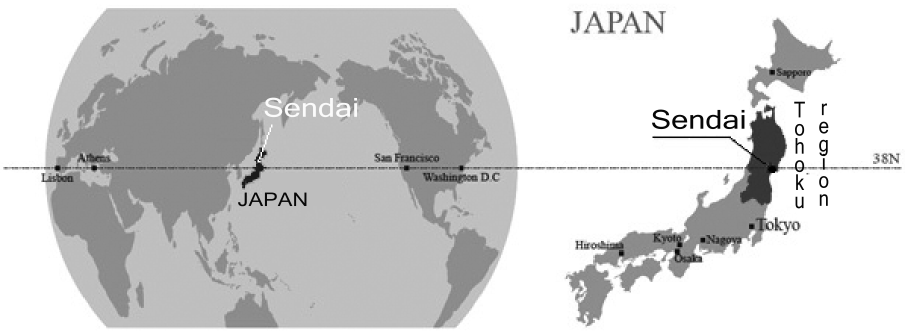

Figure A.2: Location

The city was founded in 1600, and is well known by its nickname, the "City of Trees" (*Mori no Miyako*). Sendai has a population of approximately one million, with about 80,000 students attending 13 universities, and 6 junior and technical colleges. The city is promoting international university-industry relations with a focus on strategic areas such as IT, health and welfare, environment and advanced technology. The main facilities of the Tohoku University are spread around the city in five main campuses.

- ***History***

Tohoku University was founded in 1907 as the third Imperial University of Japan, following the Tokyo Imperial University and Kyoto Imperial University. Departing from the norms of other imperial universities, it has accepted graduates from technical schools and higher vocational schools. Additionally, despite the opposition from the government at that time, it became Japan's first university to admit female students in 1913 (admitting three in that year).

With the nationwide reform of the educational system in 1949, the University assumed its present name. In April 2004, all national universities in Japan became an incorporated body and therefore legally independent of the national government. In 2007, the university marked its 100^{th} anniversary of its foundation and now has developed into one of the leading universities in the country.

Since it was established, the university's principle has been to put "Research First" while maintaining an "Open-Door" policy in order to emphasize "Practice-Oriented Research and Education." From the beginning, the university has tried to foster regional development and pursued applications for the research originating within its walls. This view was supported by two early prominent professors of the university: Pr. Hidetsugu Yagi (1886-1976) and Pr. Kotaru Honda (1870-1954). They believed that no real industrial development could be attained without basic research in major scientific fields. In alignment with their philosophy, they conducted research that substantially helped the development of Japan's materials and electronic industries.

Some famous discoveries and technological advances made at Tohoku University include the magnetic resistant KS steel and new KS steel (Kotaro Honda

1917 and 1933), the Yagi-Uda antenna (Hidetsugu Yagi and Shintaro Uda 1925), the pin diode (Jun-ichi Nishizawa 1952), the principles of perpendicular magnetic recording (Shun-ichi Iwasaki 1977), and "A method that enabled mass spectrometry analysis of biological macromolecules" for which Koichi Tanaka was awarded the Nobel Prize for Chemistry in 2002. More recently, in line with the government policies to promote technology transfer from universities, Tohoku University established in 1998 the New Industry Creation Hatchery to spur domestic industries by leveraging the intellectual resources accumulated at the university, an incubator for companies (Hatchery Square) in 2002. In 2004, when Tohoku University became an independent legal entity, it launched an Office for Research Promotion and Intellectual Property.

- ***General background***

Tohoku University is a comprehensive university comprising of 10 undergraduate faculties, 16 graduate schools, 3 professional graduate schools and 5 research institutes. It is one of Japan's leading universities, with approximately 5,700 faculty and staff and 18,000 students, which enable a student-teacher ratio of 6.3:1. The university is well ranked among aspiring students and has been selected by high school teachers as the best university in Japan for five consecutive years from 2006 to 2010 (Japanese University Ranking by the Asahi Shimbun newspaper).

Tohoku University had an annual budget of 138 billion yen in 2009 (= $1.68 billion or €1.22 billion) as compared to Harvard's $3.8 billion, Cambridge's $1.1 billion or ETH Zurich's $1.25 billion. In 2009, 14.2 % of its income came from contract research and 15 % from competitive funding, such as Grant-in-Aid for Scientific Research. (For details on the budget see Table A-3).

- ***Ranking***

Among the Japanese universities, Tohoku University is firmly established in the top league of research universities, among the four best in research performance, second in innovation performance and third in national research grant acquisition. While it is less centrally located and more remote with respect to international

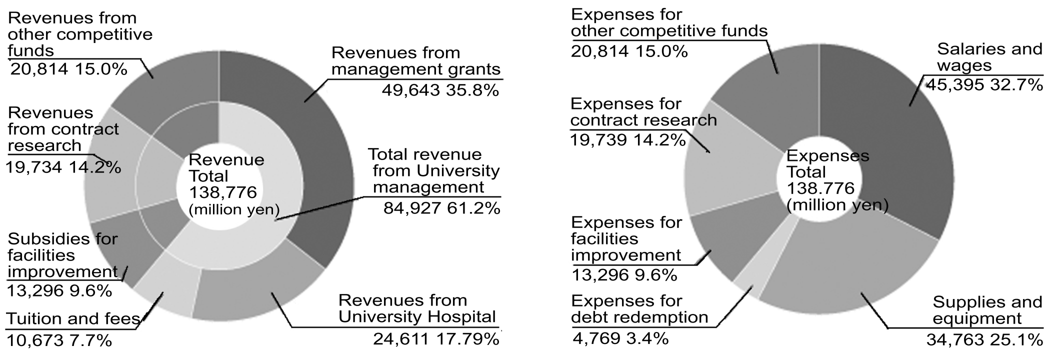

Figure A.3: 2009 budget of the university

connections, it offers the advantage of being situated in a town that is less crowded and very supportive of its university.

It is recognized on various level as a strong research university; the 2010 Shanghai academic ranking placed it in 5^{th} among Japanese universities , internationally ranking it 20^{th} in the field of engineering and technology, and 39^{th} in natural science. Additionally, Tohoku University is ranked 3^{rd} in material science and 13^{th} and 22^{th} in physics and chemistry respectively in the Thomson Scientific ESI list of most cited papers worldwide. It also has the best citation profile of any Japanese university in the humanities and social sciences.

Tohoku University has been on top for four consecutive years of the number of patents applied by Japanese universities. The average research budget commanded per teaching staff member is the highest of any national university (financial year 2005). Contributing to great extent to its research output, five research institutes are attached to the university. They are committed to sharing their research with undergraduate and graduate education and research programs: the Institute for Materials Research, Institute of Development, Aging and Cancer, Institute of Fluid Science, Research Institute of Electrical Communication, and Institute of Multidisciplinary Research for Advanced Materials.

Table A-1 gives elements of comparisons in some indicators with three other leading Japanese universities: Tokyo, Osaka and Kyoto universities. In terms of faculty, they are of relatively the same size, Tokyo University being a bit bigger. As for publications, Tohoku University ranks in the third position, it is number one for patent application and received 8.3% of the total amount of Grant-in-Aid for Scientific Research given nationwide in 2005.

Table A.1: Comparison of four universities

University	Faculty	Publication	Patent Applied	% of National Research Grant's amount
Tohoku University	2892	3766	380	8.3%
Tokyo University	3456	6341	313	16.6%
Kyoto University	2864	4522	324	10.6%
Osaka University	2978	3475	261	7.7%

Notes: All the variables are for 2005, except for faculty which are for 2010.
Publication refers to the number of papers with an address containing Tohoku University (ISI web of knowledge)
Research Grant refers to the Grant-in-Aid for Scientific Research (Jibu et al., 2008).

- ***Strategic Vison***

Tohoku University has formulated practical strategies called "Inoue Plan 2007" (after the name of the current president) to achieve the recognition of a "world-class university." The plan centers its actions on 5 areas – education, research, community service, the campus environment and organization/management. So far, the university has accomplished numerous projects in the education area. For instance, it initiated the future global leadership (FGL) program. The aim of the program is to promote internationalization of the university by expanding the number and enriching the content of courses taught in English, accepting an increasing number of international students, and providing students with greater opportunities to study abroad. The program has received funding under the Japanese government's Global 30 Project, which aims to develop the internationalization of Japan's higher education and promote centers of excellence in teaching and research.

As for other areas, the following are the on-going approaches the university is enforcing: encourage entrepreneurs to undertake business through industry-academia collaboration, upgrade its facilities to meet international standards, reorganize its human resource system in order to support the researchers' competitive skills internationally, etc.

The ultimate goal of the university is to be part of the world's top 30 universities within the next ten years. The future shall tell us if this ambitous goal is to be reached.

Sources:

- Internal documents
- Tohoku University website: www.tohoku.ac.jp/english/

APPENDIX B

SCI CLASSIFICATION

All the journals referenced in the SCI database are classified within ten fields of research. Bellow, we represent the first level of classification for those journals. We used these indicators to create our Field dummy variables in Chapter 2.

Table B.1: SCI classification of journals by research fields

	SCI Full Name	Field Dummy
1	Engineering (all)	Engineering
2	Physics and Astronomy (all)	Physics
3	Materials Science (all)	Mat.Science
4	Chemistry (all)	Chemistry
5	Biochemistry, Genetics and Molecular Biology (all)	Bio.Chem
6	Earth and Planetary Sciences (all)	Earth Science
7	Mathematics (all)	Mathematics
8	Agricultural and Biological Sciences (all)	Biology
9	Medicine (all)	Medicine
10	Chemical Engineering (all)	Chem.Eng.

APPENDIX C

QUESTIONNAIRE

The questionnaire was administered in Japanese; we provide an English translation here.

Table C.1: Questionnaire

Question 1	*In how many priority patents have you been involved with as an inventor?* 1 2 3∼5 More than 5
Question 2	*Have you been listed as an inventor on a patent with the following applicant? (Multiple choices)* Tohoku University One Company Co-application between Tohoku University and a Company Several public research institutions Several Companies Yourself Others
Question 3	*In your department, graduate school, do you systematically file for a patent when your research enables it?* Yes, if the invention is patentable we apply for a patent No, we are patenting on a case by case basis, there is no systematic policy

	No, we only patent on some rare occasions
Question 4	*Are you regularly informed of the status and prospect of your patent (grant, licensing, litigation, etc.)?* Yes No
Question 5	*What were your motivations for filing a patent?* Facilitate the commercialization of an invention through a licensed agreement To display the results as asked by the funding agency (university or government) Facilitate the negotiation of collaborations and/or contracts with industrial partners The process was imposed by a partner company To protect further development of your research Increase the visibility of my research in the industrial sphere Increase your scientific reputation The process was imposed on me by the IP office of the university or of your department Increase your income through licenses Help me to create your company What were your motivations for filing a patent?
Question 6	*Would your answer of question 5 differ depending whether the patent is solely own by the university or is the result of a co-application* Yes No Do not understand the difference between solely own and co-application
Question 7	*Following your patent application(s) what were the direct consequences? (Multiple choices)* Collaborative research to commercialized the invention

	New research collaboration with a private company or a public research laboratory Funding of some of your research by a company Increase the visibility of my research in the industrial sphere Commercialization of an invention through a licensed agreement Increase my scientific reputation Creation of your company Hiring of one of your PhD students Following your patent application(s) what were the direct consequences? (Multiple choices)
Question 8	*Would your answer on question 7 differ depending on whether the patent is solely owned by the university or is the result of a co-application?* Yes No Do not understand the difference between solely own and co-application
Question 9	*How your patenting activity has been perceived by your scientific colleagues? (only one possible answer)* Rather positive image Indifference Rather negative image I don't know
Question 10	*Did your patenting activity lead to any of the following consequences (multiple choices)* Content control Non publication Lag in publication process Less exchange of information with university scientists Less exchange of information with corporate scientists Less exchange of information in conferences

	Conflicts with other inventors Others
Question 11	*In order to patent your research did you experience delays in publishing your research? If yes how long was that period? (Please choose one of the following).* Less Than 6 months 6 to 12 months 1 and 2 years More than two years Don't know
Question 12	*In general, how do you present the results of your research collaboration with an industrial partner* On the company side, they give priority to patents On the company side, they give priority to publications On your side, you favor patents On your side, you favor publication You and the company decide depending on the characteristics of the results The company wants to patent, you want to publish, you negotiate an arrangement with the company
Question 13	*Has one of your patented inventions been commercialized?* Yes No
Question 14	*What was the influence of the patent in your technology transfer initiative? (only one possible answer)* Yes, without the patent application the invention would not have been exploited Yes, without the patent application the invention would have been exploited but the patent has facilitated this exploitation No, no role at all I don't know

Question 15	*Did the possibility to be granted patents influence the nature of your research? (only one possible answer)* Yes, I try to orient my research in fields where I know it will be possible to apply for patents (1) No I don't know
Question 16	*How do you consider patenting in your field of research?* Patenting is essential Patenting is an option alongside publications and conferences (2) Patenting is not very important Others
Question 17	*Rank according to their importance theses different channel of technology transfer toward industry.* Patent and license Publication Consulting Conversation Co-supervision of students Recruiting/hiring Conference Research collaboration
Question 18	*Have you already been disturbed in your research by patents held by other inventors?* Yes, I have already been obliged to reorient my research in order to get around a patent held by a tierce organization Yes, my lab has already been obliged to buy licenses from other inventors in order to be allowed to pursue research in a given technological domain No
Question 19	*Have you already been implied in a patent litigation (Trial, etc.)?*

	Yes
	No
Question 20	*According to you, university patenting:*
	Facilitates the commercialization of academic inventions
	Increases the incentives of scientists to do research
	Increases the bargaining power of universities in front of industrialists
	Facilitates the development of collaborations between universities and firms
	Enables to finance public research
	Increases the visibility and credibility of scientists
	Decreases the diffusion and dissemination of academic research
	Reduces incentives to do basic, non patentable research
	Reduces trust and thus decrease collaboration and interaction among scientists
	Increases the costs to access scientific information
Question 21	*Have you ever conducted R&D activities in the private sector?*
	Yes
	No
Question 22	*Since you finished your PhD, have you ever worked and conducted research in a foreign country?*
	Yes
	No
Question 23	*Currently, what is your main research preoccupation?*
	Mainly basic research (rather than concrete problem-solving, your aim is to create new theories and knowledge)
	Mainly applied research (developing theories and knowledge, that aims at solving some concrete problems)
	Rather basic than applied research
	Rather applied than basic research
	Both basic and applied research

	Not aware of the above categories
Question 24	*Please tell us about your current main topic of research?*
	Equipment, devices, new materials, synthesis, development, and manufacturing
	Creation of models and simulations methods
	Both of the above categories
	Other

RÉSUMÉ

La recherche académique est aujourd'hui perçue comme un puissant moteur de l'activité économique, confrontant ainsi les chercheurs académiques à de nouvelles demandes et opportunités dans la conduite de leurs travaux. En effet, la création de savoirs académiques n'est pas le fruit d'individus isolés et coupés du monde, comme nous nous pouvons parfois l'imaginer. Il s'agit plutôt d'un processus complexe où l'industrie joue un rôle croissant, en particulier dans certains domaines technologiques. Un équilibre en constante évolution entre les impératifs universitaires et industriels contribue à façonner l'agenda et les pratiques des chercheurs académiques. Comment la capacité des chercheurs universitaires à produire et diffuser les connaissances scientifiques et techniques est-elle influencée par ce nouvel environnement? C'est la question centrale de cette thèse. Nous avons construit différents indicateurs et utilisé plusieurs approches méthodologiques pour appréhender cette question. L'objectif est de caractériser les mécanismes qui peuvent expliquer l'émergence de nouvelles stratégies de production académique, ainsi que leur évolution dans le temps. Nous montrons que les normes et pratiques de la communauté universitaire évoluent en réponse à l'émergence de nouvelles incitations. Néanmoins, les acteurs académiques sont loin d'être passifs dans ce processus. Nos résultats empiriques sont basés sur l'étude de l'Université du Tohoku, institution à la pointe de la commercialisation de la science au Japon.

Mots clés: innovation, recherche académique, science ouverte, transfert technologique.

ABSTRACT

Academic science is now considered a tool of economic progress. One consequence of this trend is that academic scientists face new demands and opportunities while conducting their research. Indeed, the creation of academic knowledge does not originate from the talents of isolated geniuses cut from distinct cloth, as it is often described. Rather, it is a complex process where the industry plays an increasing role in some technological fields and situations. An evolving balance between academic and industrial imperatives contributes to shape the academic agenda and research practices. How faculty members produce and diffuse scientific and technical knowledge, conditioned by this new environment, is the central question of this thesis. Accordingly, we constructed various indicators and used different methodological approaches to deal with this question. The aim of this study is to characterize the mechanisms that explain the emergence of new strategies by academics, as well as their evolution in time. We show that the norms and practices of the academic community are evolving in response to new incentives; nevertheless, the academic actors are not passive in the process, as they are actively designing new hybrid strategies. In order to illustrate these thoughts, we analyze the behaviors of faculty members at Tohoku University, which is at the forefront of the commercialization of academic science in Japan.

Keywords: innovation, academic research, open science, technology transfer.