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ESSAYS ON THE IMPACT OF INNOVATION ON LOCAL EMPLOYMENT GROWTH:

Application to Luxembourg

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soutenue le : **16 Mai 2017**

En vue de l'obtention du grade de : **Docteur en Sciences Economiques**

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First part:

General overview of the literature

Chapter 1 : General overview of the literature

1. Introduction

Many analyses have focused on the link between innovation and productivity using different kinds of proxy (patent, survey data, etc.) and different levels of analysis (see *e.g.* Griliches 1994, for a review of this literature). The development of firm-level data these two last decades has provided new opportunities for focusing empirically on agents introducing (endogenously) technological change. Such opportunities were followed by the development of econometric models (see *e.g.* Crepon *et al*. 1998, Mairesse and Mohnen 2009, Mairesse and Robin 2017) dealing with econometric issues arising with the survey data available, *i.e.* mainly cross-section data deriving from the Community innovation survey carried out in European countries. The development of econometric models, and among them structural models, linking innovation and employment at firm-level is more recent. The important contributions to be stressed in this field are Harrison *et al*. (2014) and Hall *et al*. (2008).

However, such a distinction between analyses focused on productivity or on employment has important implications. Basically, both types of analyses are likely to differ due to two adjustments affecting jobs. The first one is compensation or the displacement mechanisms that follow the introduction of innovation. Indeed, taking advantage of innovation, firms may reduce the number of employees to obtain the same amount of output, thus increasing labour productivity as such in an opposite way. On the other hand, innovation may increase market demand for a firm’s products, through decreases in price or product novelty, positively sustaining employment growth whilst being more in line with the expected direction of a firm’s productivity change as induced by process innovation. The second one is skills bias or employment polarization induced by technological change, as a product or process innovation may be complementary to, or substitute for, different kinds of jobs defined on the basis of their skills and tasks requirements. Moreover, employment may come into play either as an input or as an output of the innovation process. Indeed, in order to complete the setting up of new or updated technologies firms may choose between hiring new employees or training the incumbent ones (Bauer and Bender 2004). Where the adoption costs are higher relative to the job creation costs, firms are also assumed to destroy the old jobs and to hire new workers with the necessary skills to work with the new technology and/or the new organizational environment (Mortensen and Pissarides 1998). Putting it all together, even if productivity growth may support employment growth, both are different targets and both may equally vary in opposite directions. Specific attention has, therefore, to be paid to the types of innovation introduced, the skills and tasks requirements of the firm’s jobs, and the firm's time frame, in any identification of the effect of innovation on employment changes.

The inclusion of a spatial dimension in firm-level studies is also rather underdeveloped. Many analyses that include a spatial dimension are either focused at aggregate level through a macro- or regional perspective, or are based on ad-hoc micro-data collections, reducing the opportunities for providing overall evidence. It should, however, be pointed out than in a few countries such as Sweden, some papers focusing on the link between innovation and productivity through Community Innovation Survey (CIS) data, have introduced a spatial dimension (see *e.g.* Lööf and Johansson 2014). However, those papers focus mainly on variations across regions, often putting aside variations within regions that are likely to be the most important source of variability. Reported gaps are not in line with, firstly, the empirical evidence regarding spillovers decay across space and, secondly, the substantial differentials across local areas with respect to their input in terms of capital, labour and technologies. The exclusion of local specificities and externalities from the analyses are likely to induce biases as far as those would be correlated with some regressors and random disturbance. Moreover, the existence of local externalities relies on market failures induced by sharing, matching and learning mechanisms operating across different markets. The design of any place-based policies dedicated to addressing these market failures therefore requires an adequate knowledge of local specificities and externalities mechanisms.

Furthermore, the inclusion of a spatial dimension strengthens the gap between productivity change and employment change. Indeed, the impact of both agglomeration effects and spatial equilibrium effects on growth (including workers mobility) may be different depending on whether it concerns productivity or employment growth. However, these gaps are not well established and recognized, leading many scholars to use employment and productivity changes as a proxy for each other. One basic explanation of this lack is that productivity or employment data are not always easily available, leading some scholars to focus only on the one available. It has to be stressed as well that the inclusion of space in the analysis makes it even more complex. Indeed, many mechanisms have to be disentangled to identify their impact on employment. Among others, many econometric, data-set, and measurement issues have to be solved. As regards econometric issues, one can note the potential effects of some confounding factors, as well as the potential bias induced by *e.g.* product innovations that are assumed to be endogenous, or the potential multicollinearity between location variable(s) and firm-level characteristics, and finally the potential, non-random shocks faced by firms across different local areas. As regards data-set issues, one can notice the non-homogeneous distribution across space of firms and workers' skills that needs to be reported in the data-set, as well the limitations induced by the survey coverage and the questionnaire used. As regards measurement issues, one can stress that the overall phenomenon has to be split between direct and indirect effects, the former corresponding to intra-firms effects reported in micro-economic analyses, while the latter includes, amongst others, agglomeration effects, neighbouring effects, multiplier effects or spatial equilibrium effects. One can also focus on skills bias or polarization effects. Insofar as these different indirect effects and skills biases are likely to induce market failures, for which place-based policies may be designed, an adequate measurement of them is highly necessary.

Even if our aim is to focus on employment, this introductory chapter does not focus directly on it. Three main sections are used to introduce the mechanisms of technical change across space regardless of their effect on productivity or employment, before focusing on employment. A first section deals with general models of technological change by focusing on localised technological change (Atkinson and Stiglitz 1969). The introduction of innovation is assumed to have varying effects according to basic conditions that a firm has to face. Firstly, technical improvements affect a product's components to different extents and firms have to take into account current and future price when investing in a new project. Secondly, even if firms are myopic agents with bounded rationality, the introduction of technological change diverts from a firm's deliberate and intentional results. In addition, firms' adjustments follow a series of sequential choices that are relatively irreversible, especially for radical innovation.

A second section deals with the role of externalities. Every analysis using a competitive equilibrium view has to take them into account. Two main types of externalities can be distinguished, *i.e.* knowledge spillovers, on which innovation studies focus, and local externalities used mainly in urban economics. We also stress recent papers dealing with location as a non-replicable factor for which the inclusion of externalities is not mandatory in the empirical set-up.

A third section is about the non-homogeneous distribution across space. The distribution of skilled workers, firms' capabilities, market opportunities, local input, as well as first nature advantage and disadvantage, are all assumed to vary greatly across space. Moreover, the spatial distribution of some kinds of individuals/firms may depend on the spatial distribution of some other kinds of individuals/firms, due to complementarity between them. All these disparities are likely to explain a large share of the variance of the dependent variable and have therefore to be taken into account in order to adequately identify the mechanisms induced by technological change.

The fourth section is focused on employment. This large section makes a distinction between four types of analyses, *i.e.* firm-level analyses, biased technological change, adjustment mechanisms at aggregated level and spatial equilibrium models. A first sub-section is about firm-level analyses. These aim at assessing finer-grained phenomena, taking into account, amongst others, the direct effect of firm's resources, including a firm's environment, as well as some selection effects. The greater availability of firm-level data provides increasing research opportunities. A second sub-section deals with biased technological change. This is focused on formal models and empirical results regarding the effect of technological change on individuals with varying skills or involved in varying tasks. A third sub-section focuses on the adjustment mechanisms at aggregated level and extends the analyses to the indirect or inter-firms effects of technological change. Such extensions provide a way of focusing on the net effect of technological change that results from direct and indirect effects. Those indirect effects include, firstly, effects at various levels of analysis *i.e.* sectoral, local and national level. They also include agglomeration effects, neighbouring effects and multiplier effects. The last subsection is about spatial equilibrium models. These aim to consider the mobility of workers as well as any adjustments in housing markets as additional general equilibrium effects.

2. From neutral technological change to localised technological change

Technological progress was assumed to shift the function of production by increasing the output per capita by a given amount. As such, technical improvements following research and learning by doing, including spillovers effects, ought to affect the components of different products to the same extent. However, such neutral technological change was challenged by the concept of localised technological change introduced by Atkinson and Stiglitz (1969).

According to Atkinson and Stiglitz (1969) "Localised" technical progress is basically defined as improvements made to specific components of the product. Localized technological change therefore implies an uneven shift in the technological frontier in different ranges of the input. Technological change is also assumed to take a factor-augmenting form. The graph below, from Atkinson and Stiglitz (1969), shows the extreme case when technological change is completely localised to one technique (without spillover effects favouring other techniques). It highlights what is assumed by the old view (table 1.1, fig 1), with improvements to every technique, and what is hypothesized by the new view (table 1.1, fig 2), with improvements for a limited number of techniques and, in the extreme case, only one.

Table 1-1: From the old to the new view of technological change

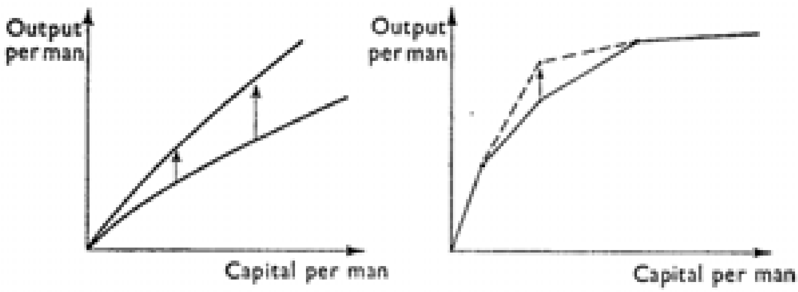

Fig. 1. Fig. 2.

Source: Atkinson and Stiglitz (1969)

Firms producing such a product have a choice between two technologies, *i.e.* labour intensive or capital intensive. Labour intensive technologies are assumed to increase productivity through learning by doing, and learning by doing is thus internalized by the firm. As a firm's choice will affect the productivity of the single technology adopted, it has to take into account the productivity improvement that will be induced by its choice when selecting among the available technologies. Such an improvement will afterwards positively impact the price of this technology. Only in the case where the increase in productivity is higher than the increase in price (capital or wages), will firms adopt this technology. In addition, firms will subsequently switch to another technology if it expects lower marginal costs from it compared to the first one. Current and future prices have therefore to be taken into account.

Even though Atkinson and Stiglitz (1969) point out that, in addition to learning by doing, firms can also focus on research activity for enhancing their productivity, further development of their model emphasized learning by doing. Following these developments Acemoglu (2015) provides a formal model of technological change through learning by doing. As such, technological change is modelled as labour-augmenting. It also has to be highlighted that models of skill-biased technological change usually model technological changes according to this labour-augmenting view (see 5.2).

Antonelli further develops this literature by focusing on the inducement mechanisms of technological change and the potential bias resulting (1998, 2004, 2006a, 2006b). He basically assumes that firms are myopic agents affected by bounded rationality that may respond to their changing conditions by introducing technological change through a series of decision-making processes. Firstly, firms are induced to introduce technological change when unexpected events occur and firms' current conditions seem inadequate for facing this event. As such, firms are not assumed to react only by adjusting their output or prices, and innovation becomes a deliberate and intentional result deriving from firms' decision-making. Secondly, as myopic and bounded rationality agents, firms are assumed to not perfectly anticipate all the possible conditions in the world and therefore to not be able to compute all the costs and benefits generated by the introduction of innovation. Thirdly, firms' introduction of technological change is seen as the consequence of sequential choices made by firms. Firms basically have to choose among different opportunities in order to increase their in-house knowledge resources. Such opportunities are the following: to invest in research, to acquire external knowledge, to take advantage of new technological opportunities and to accumulate knowledge through different kinds of learning, such as learning by doing, learning by using, learning by interacting with customers, etc. Such changes, through *e.g.* specific firms' investments, may be highly irreversible, thus constraining dynamic firm-level adjustments. However, as every firm's choice may have indirect effects on other players by modifying firm-level opportunities, the environment in which firms are embedded has to be taken into account.

This scheme provides an integrated framework for the analysis of innovation, adoption and diffusion. Adoption is seen as an active process as it needs to solve a series of idiosyncratic problems of adaptation and integration (Antonelli 2006b). The dynamic of such an adoption process is assumed to also generate an S-shape diffusion path at the aggregate level in line with the diffusion literature focusing on the epidemic and contagion model of innovation (Griliches 1957, David 2015). Further advances are made by considering the distinction between general and contingent technological change. While in the first case the output elasticity of every production factor is affected, in the second one only their composition and weight with respect to the elasticity of the output is affected. Contingent technology therefore only positively impacts the overall factor productivity through the substitution of less productive inputs by more productive ones (Antonelli 2006 b). As such they are not fully neutral, even if they do not shift the overall productivity level. According to Antonelli (2006a) contingent technological change is the result of the incremental introduction of a myriad of small changes after the main shift effect has been generated. In such a case, unexpected changes that firms have to face in both product and factor markets are less important and more reversible. As such, contingent changes are assumed to induce a lower technological bias.

3. The critical role of externalities

The Spatial Impossibility Theorem assumes that, insofar as economic activities are not perfectly divisible or cannot sustain ever increasing returns, no competitive equilibrium involving transportation can exist, if space is homogeneous, transport is costly and preferences are locally non-satiated. A finite number of locations, consumers and firms are also assumed in this framework. Conversely, assuming economic activities are perfectly divisible, a competitive equilibrium might exist, but would be such that each location would operate as an autarchy. However, as recognised by Starrett (1978, p. 27) economic activities are not perfectly divisible. The indivisibilities put aside, one has to assume either land as being heterogeneous or increasing returns at local aggregate level (externalities) in order to sustain competitive equilibrium in line with the neoclassical view (Arrow and Debreu 1954) and involving transport costs. In other cases, one has to assume imperfect competition and focus on the set-ups modelling it. Combes *et al*. (2006b, ch.2 §5) detail a series of models that may be used for that purpose, including monopolistic and oligopolistic competition.

Such results provide the theoretical basis for any empirical strategy. The economics of innovation and new technology usually put knowledge spillovers to the fore (see 3.2). On the other hand, urban economics is hardly focused on the inclusion of externalities as a modelling strategy (see 3.3). Moreover, the high concentration of economic activities and the fact that innovative activity tends to cluster to an even greater extent (Audretsch and Feldman 1996), provides an empirical validation of the inclusion of externalities in our analyses. A last subsection will be dedicated to recent contributions aiming at providing a dynamic theory of spatial development. These focus on location as a non-replicable factor (see 3.4).

3.1 Knowledge spillovers

One important externality which has received a lot of attention in the literature is knowledge spillovers. Spillovers are at the heart of long-term growth in the economic growth literature (Klenow and Rodríguez-Clare 2005). Technological externalities have especially received attention in endogenous growth literature (see Romer 1986, Lucas 1988) including through monopolistic competition (Romer 1990, Grossman and Helpman 1991, Aghion and Howitt 1992).

The presence of externalities may be derived empirically from basic examinations at different levels of analysis. Indeed, the estimation of the knowledge production function at lower levels of analysis, *i.e.* from national to firm-level, provide, as Audretsch and Feldman (2004) have stressed, less and less clear impact of knowledge input or output (2004). Such a result suggests, either that the aggregated level is more appropriate, or that some positive externalities, which would be spatially bounded, have to be considered, especially at firm-level. As such, knowledge spillovers have to be defined not only on the basis of their non-exclusive and non-rival use (Arrow 1962), but also by the following additional feature, namely their decaying effects across space.

A long series of arguments can be provided to explain these insights. The first one is physical proximity to educated workers. Physical proximity is assumed to provide a better sharing of ideas fostering both innovation and technology adoption. Lucas (1988) provides a theoretical model in which human capital has two different effects. The first one is a positive shift in the productivity of the individual investing in his human capital. The second one is the average increase in productivity of other workers. Such an effect is an externality because, "though all benefit from it, no individual human capital accumulation decision can have an appreciable effect on average human capital, so no one will take it into account" when investing in his own human capital. The second one is the cost of search or the endogenous skill-biased technological change with physical and human capital as complements. Acemoglu (1996) proposes a micro-founded model for this in which a job search is expensive for workers and firms, and physical and human capital are complements. As soon as some workers in a city increase their level of education, these complementarities should induce firms from that city to increase their physical capital. Moreover, as a search is costly, some of the workers who did not improve their education would, in a third step, take advantage of this additional physical capital, thanks to the two complementary factors, thus increasing their productivity and wages with respect to similar workers in other cities.

Many additional arguments that focused on the features of knowledge and the value added by social interactions have been provided as well. Firstly, a distinction has to be made between knowledge and information. Knowledge is hypothesized to be tacit and difficult to codify. Secondly, knowledge may be sticky (Von Hipple 1994), *i.e.* highly contextual and uncertain. Thirdly, many of the interactions in R&D and human capital formation occur outside the market and are influenced by social processes through the expectations, preferences and constraints of related economic agents (Manski 2000). Face to face interactions may increase the transmission of knowledge integrating such features. In addition, exchange of information among co-located firms engaged in innovation may reduce the uncertainty of innovation activity (Feldman 1994).

Moreover, as knowledge spillovers are non-homogeneous across space, firms may adopt a strategy to take advantage of the transmission mechanisms. As such, knowledge diffusion is highly endogenous and firm-level analyses may be used to fine-tune the knowledge spillovers exam. In this vein, different arguments have to be highlighted. Firstly, knowledge transmission is not confined to knowledge externalities, as knowledge may be purchased and sold. Secondly, individuals (including researchers) are holders of knowledge externalities. Hiring them may therefore be an adequate strategy to foster a firm's absorptive capacity. Thirdly, local ties opportunities induced by an endogenous firm's location, within *e.g.* a specific cluster, also favour the diffusion of knowledge. Fourthly, employees may launch their own small firm to take advantage of their own knowledge and findings. Empirical evidence shows that small firms are highly innovative in some markets (Acs and Audretsch 1987). However, the latter finding may also be explained by small firms taking better advantage of R&D spillovers, as highlighted by Acs *et al*. (1994).

Moreover, Johansson (2005) provides a detailed picture of knowledge externalities mechanisms. He highlights six features of knowledge externalities: (1) their economic nature: pecuniary and non-pecuniary, technological, (2) their sources: embodied knowledge, disembodied knowledge, intra and inter-regional sources, proximity, (3) their recipients: agents involved in the same economic activity or in different economic activities (*i.e.* MAR vs Jacobs externalities), (4) their mechanisms: formal and informal interactions, active knowledge search, mobility of agents, (5) their spatial diffusion: knowledge may be spatially bounded or diffused widely, (6) their effects: efficiency externalities[1] and innovation externalities[2]. However, in order to identify these different mechanisms, a microeconomic perspective dedicated to distinguishing among different players and their varying contributions has to be

[1] An efficiency externality relates to static differences between regions with respect to the productivity and firm-level cost per unit output.
[2] An innovation externality relate to a dynamic phenomenon induced either by a change of economic efficiency through new routines, or by the introduction of new products, the increase of product diversity and similar other novelties.

considered. In order to do so, different methodological and econometric issues (*i.e.* endogeneity of knowledge transmission, sorting of firms, lack of micro-foundation of the mechanisms, etc.) have to be overcome.

3.2 Local externalities

Why does performance in innovation differ across regions even when inputs from the knowledge production function are held constant? Some scholars highlight the specific effect of the local culture (Malecki 1997), while some focus on the local externalities deriving from the local structure and therefore on the agglomeration externalities. The basic idea is that local productivity shifts are not exogenous but are instead generated/sustained by local micro-based mechanisms, *i.e.* sharing, matching, learning (Duranton and Puga 2004). Externalities are, as such, localised in space through the local structure.

Three main types of externalities, assumed to sustain the local density of firms, have been highlighted in the literature: the Marshall-Arrow-Romer or localization externalities, the Jacobs or urbanization externalities and the Porter externalities. According to the first one, the concentration of large, similar/related firms enhances competitiveness. For the second one, diversity promotes competitiveness. The third one emphasizes the intensity of local competition. Empirical studies typically find a strong and statistically significant positive relationship between density measures of economic activity and productivity (*e.g.* Ciccone and Hall 1996). Focusing on employment growth, Glaeser *et al*. (1992) and Henderson *et al*. (1995) have sought to separate the influence of externalities. De Groot *et al*. (2009) have synthesized the available empirical evidence on this topic through a meta-analysis. They conclude on an overall positive effect of diversity and competition on growth. However, they also highlight the strong sectoral, temporal and spatial heterogeneity of their results. pointing out, amongst other things, the stronger effect of diversity in high-tech sectors.

According to the micro-determinants of agglomeration effects, firms co-locate so as to enhance the following properties: sharing, matching, and learning (Duranton and Puga 2004). Sharing relates to the economies of scale derived from indivisible facilities (*i.e.* local infrastructure) developed at local level, the division of risks over a larger number of operators, and scale gains deriving from variety and specialization (*i.e.* the

MAR and Jacobs externalities). Matching refers to a better quality of matches or a higher probability of matches between employers and employees, buyers and suppliers, or other kinds of partners likely to sustain local projects. Learning is about the dynamic mechanisms that strengthen the creation, diffusion and accumulation of knowledge over time. Additional contributions dedicated to providing empirical evidence to these micro-foundations have extended this list by considering *e.g.* home market effects or rent seeking (Rosenthal and Strange 2004). Even if these sources are diverse, a Marshallian equivalence was suggested, as they are supposed to support urban growth in the same way (Duranton and Puga 2004, Rosenthal and Strange 2004). However, in addition to these mechanisms, one also has to focus on the sorting of skilled workers and on the selection of more productive firms and entrepreneurs (Combes *et al*. 2012a) in order to identify their respective contributions.

In addition, one has to focus on local labour markets. These local markets are assumed to provide varying opportunities for sharing, matching, learning, and mobility across these markets might sustain adjustment mechanisms. It is, therefore, important to examine the peculiar geographical scope of our study. Duranton and Overman (2005, 2008) found a peculiar spatial range for labour market pooling (less than 50 km). Some national statistical offices have provided formal delimitations for these local areas. The United Kingdom was *e.g.* divided into 243 "Travel-to-work areas", France into 322 "*Zones d'emploi*" and Italy into 784 "*Sistemi locali del lavoro*". Basically, these local markets, which have to be distinguished from administrative regions, are defined according to the intensity of labour market commuting flows. Using similar criteria, one can make the distinction between two to five local labour markets in our case (see Dautel and Walter 2014 and chapters 2, 3, 4, 5). Assuming that firms and workers' characteristics vary according to local areas (as well as the local externalities generated), it has to be highlighted that the inclusion of local labour market data within firm-level data requires controlling for potential confounding effects induced by sorting and likely to bias any empirical exams.

Moreover, one may wonder to what extent adjustments occurred at a finer scale of analysis or vary more gradually across space. Basically, one may assume that the centripetal forces that pull economic activity and the centrifugal forces that push it are operating simultaneously within local labour markets and strengthen the adjustment mechanisms. According to Combes and Duranton (2006a) a firm's location choice results from the trade-off between pooling advantages and poaching costs. They assume too that knowledge is partly embodied in workers and that workers accumulate human capital on the job. A dynamic wage premium is therefore assumed. To provide foundations for the accumulation of human capital on the job they refer to the labour literature on workers' flows across firms (Rosen 1972), where workers face the trade-off between occupations offering low real wages but faster acquisition of human capital (agglomeration areas) and occupations providing higher real wages but lower learning opportunities (peripheral areas).

3.3 Location as a non-replicable factor

Assuming the presence of non-replicable factors, perfect competition on the input and output markets can lead to optimal innovation without any inter-temporal externalities on firms' market power (Desmet and Rossi-Hansberg 2012). Such non-replicable factors contrast with the features of knowledge assumed by Arrow, *i.e.* non-exclusive and non-rival use of knowledge (Arrow 1962). The main example of such a non-replicable factor is, for Desmet and Rossi-Hansberg, land. Innovations are as such location-specific. Basically, in addition to these non-replicable factors, no knowledge spillovers or local externalities have to be assumed, nor any monopolistic competition. Conversely, in the hypothesis that firms facing perfect competition without any externality will be driven to make no profit (as innovations diffuse freely), thus hampering investment, innovation can be funded with land as a non-replicable factor.

Desmet and Rossi-Hansberg (2012), set up a simple model for supporting this argument. Basically, two types of players are assumed, the owner of a given plot of land, and firms competing for such land. Indeed, in order to innovate, firms bid for the land as much as they are able. Only the successful firm is allowed to produce at this place and to take advantage of the benefits resulting from the innovation activity which is launched. Firms are therefore assumed to invest optimally to have access to this non-replicable factor, and the price of land is assumed to include all the benefits and costs of localised innovation. At equilibrium, price equals marginal costs, including the price of land, firms innovate but make zero profits, and the level of innovation is efficient. Desmet and Rossi-Hansberg (2012) also show that potential externality through imperfect appropriability can be maintained, insofar as temporal lag may be introduced or lower productivity may be considered for other places. In such cases, innovations are less optimal in other places due to either a temporal or a spatial diffusion process.

Desmet and Rossi-Hansberg (2012) provide an empirical validation of their model by showing a positive and convex relationship between the local cost of innovation (including land price) and the local level of technology across (229) US Metropolitan Statistical Areas. This result suggests therefore that innovation gains and costs are embedded in land prices and as such are location specific. This result remains to be checked within metropolitan regions. However, in order to do so, data availability limitations have to be overcome.

In addition, they emphasize two implications of their model. Firstly, as firms facing competition for land access are assumed to pay as much as they are able for such land, all extra profits ought to be captured by the land owner. Secondly, as no externalities are needed for funding innovative projects, their model suggests that granting monopoly power through *e.g.* patents is not needed. However, these two implications depend critically on the granularity of their model. In a companion paper, Desmet and Rossi-Hansberg (2010) fine-tuned their model by including a third type of actor, namely workers operating as an input in the production process. In addition, they extended the adjustment mechanisms of their model by bringing in the mobility of firms and workers as well as technology diffusion.

4. Non-homogeneous distribution over space

The distribution of skilled workers and firms as well as entrepreneurial skills varies across space and in market opportunities, in local input and first nature advantage or disadvantage. Indeed, skilled workers may be attracted to urban areas in order to take advantage of static or dynamic wage premiums. In addition, firms or entrepreneurs may choose their location according to the trade-off between local advantages, including the agglomeration of economies, and local disadvantages, including the cost of business premises. At least two types of non-random sorting may therefore have to be considered. Moreover, this sorting is assumed to take place at the level of local labour markets (or functional regions) whereas the micro-determinants of agglomeration effects stand out: sharing, matching, learning (Duranton and Puga 2004).

Three main strategies may be followed according to the extent to which individual data with respect to firms or employees is available. The first one is to augment the model by additional control variables describing workers, firms and local characteristics. It is assumed in this approach that no potential omitted variables, correlated with both one explanatory variable and random disturbance, were still missing in this augmented model. It is also assumed that the location of skilled workers, as well as knowledge-intensive firms, are rather exogenous. A second strategy is to include both location and time-fixed effects, as well as workers' skills or firms' sectoral affiliation. It should be noticed that the local fixed effects have to be set-up at highly disaggregated level. One issue may be that, due to data availability, this level of analysis corresponds to local labour markets likely to be used as explanatory variables in the analysis. A choice would, therefore, have to be made between using the local labour market as a fixed effect in order to control for sorting, or as an explanatory variable, and therefore with potential identification issues to be solved. Among them, one may notice the potential endogeneity of such a local market variable due to omitted variables that would be correlated with both this variable and random disturbance[3]. A third strategy is to introduce individual fixed effects by taking advantage of panel data (Combes *et al*. 2008). Such a strategy purges the estimates from the impact of individual characteristics. This option is especially welcome when dynamic adjustments are assumed. Moreover, panel data may provide additional information regarding firms' demography and firms' mobility across space. Indeed, firms facing a shock are likely either to move to other areas offering more adequate opportunities, or to file for bankruptcy. One could model such firms' behaviour as general equilibrium effects (see 5.4).

Potential confounding factors and reverse causality also have to be considered. Indeed, at least two alternatives hypotheses of static or dynamic wage premiums may explain the sorting of skilled workers. Firstly, high-skilled and productive individuals may be attracted to large cities by the cultural amenities offered (Moretti 2004). It can also happen that a local authority subsidizes cultural services in order to foster their

[3] See below on how to control for potential confounding factors.

attractiveness for high-skilled and creative individuals (Falck *et al*. 2011). Secondly, high-skilled couples may be attracted by better opportunities for dual-earner couples. According to Costa and Kahn (2000) the diversified economic structure of metropolitan areas offers better matching for husband and wife job opportunities. In both cases, the correlation between high-skilled sorting and the outcome may be induced by either confounding factors (cultural amenities or opportunities for dual-earner couples) or a reverse causality (higher outcome strengthening the sorting of high-skilled workers). One way to deal with such an issue is to follow a shift-share instrument strategy (Bartik 1991) by constructing a measure of the endogenous variable that is highly correlated with it, but is only driven by a shift from the supply side. This measure, used as instrument[4], combines the national shock across industries with the local industry structure (see Baum-Snow and Ferreira 2015 for a review of this strategy).

Finally, the sorting of specific types of workers or firms across neighbouring areas may suggest potential complementarity between different kinds of workers and different kinds of firms. In line with this assumption, Forslid and Okubo (2014) highlight the complementarity between high-skilled and low-skilled firms. Focusing on workers, Eeckhout *et a*l. (2014) providence evidence regarding extreme skill complementarity of workers, while the results in Behrens, Duranton and Robert-Nicoud (2014) support top-skill complementarity. All this suggests, therefore that some workers and some firms take advantage of close proximity. In order to take them into account, control for interaction effects, trough cross-sections (Lee 2007) or panel data (Bai 2009) may have to be considered (see 5.3.c).

5. Literature examining the link between technology and employment

Technology has two main direct impacts on employment, firstly a firm-level effect on those introducing new products or processes (5.1) and secondly, a worker-level effect through increasing aggregate demand or productivity for those with specific skills or involved in specific tasks, as technological change is not neutral (5.2). Pianta (2005), providing an overview of the field, called these two direct effects, ‘quantitative’ for the first one, the number of jobs and hours of work usually being the focus of such analysis,

[4] A standard exclusion restriction is required as well as a strong first stage.

and ‘qualitative’ for the second one, as job rates and wage inequality across skills and tasks are usually examined. These two effects are assumed to induce two additional effects at the aggregate level, *i.e.* some adjustment mechanisms (5.3) and some spatial equilibrium effects (5.4), which will be examined as well. The link between innovation and employment examined at different levels of analysis (*i.e.* firms, industry) including spatial levels of analysis (cluster, local labour market or functional regions, the overall economy) do indeed capture different mechanisms.

5.1 Firm level analysis

According to Duranton and Kerr (2015) the most important change in empirical research on agglomeration economies over the last two decades has been the creation of firm-level datasets. This favours finer-grained analyses focusing on the specific role played by firms, and allowing to take into account its neighbours through spatial proximity or other kinds of distance between them (Boschma 2005). This has opened the door to new types of analyses across space, such as spillovers decays, firms’ selection (with firms’ panel data), the matching of firms and workers (with employer-employee data). In addition, such firm-level data allows to take advantage of the micro-econometric tool box. A large part of such a tool-box can, however, already be used with adaptations at city or regional level (see Baum-Snow and Ferreira 2015 for a review). Finally, the microeconomic studies that have focused on the role played by firms, provide a bridge between the economics of science and innovation and the urban studies that emphasize the central role of agglomeration phenomena.

More specifically, the firm-level data that will be used comes from different waves of the Community Innovation Survey (CIS) carried out in Luxembourg. In addition to the standard data collected in other European countries, the spatial location of firms at the level of local labour markets was introduced into our datasets. To our knowledge, only a few countries have done so, and in most cases at a more aggregated level. This lack appears to be due to the exclusion of any kind of spatial dimension in the stratification of the sample of countries. One exception, however, is the study of Grillitsch and Nilsson (2015) focusing on knowledge spillovers between Swedish municipalities. A first point deals with the information provided by the CIS survey sustaining research opportunities for firm-level analysis of technological change. A second one focuses on the empirical evidence that derives from this survey.

5.1.a Kinds of information provided by the CIS:

The Community Innovation Survey makes the distinction between different types of innovation, *i.e.* product, process, organizational and marketing innovations, in line with a Schumpeterian view (Schumpeter 1934). It also provides information regarding firm involvement in innovation activity through firms' resources dedicated to R&D and other kinds of investment in support of their innovation projects (External R&D, Acquisition of machinery, Equipment and software, Acquisition of external knowledge, Training for innovative activities, Market introduction of innovations, Design). Innovation can indeed be carried out with or without R&D. In addition, the survey's respondents have to point out whether their product innovation is new to the firm, new to their market or new to the world (introduced in CIS 2010). A distinction is also made between innovations developed in-house, and the adoption of innovations developed somewhere else and more in line with contingent innovations (see Antonelli 2006a). The survey's respondents further have to value the success of their product innovation according to the percentage of these products in total turnover at the end of the three years reference period of the survey. All these details are important as the type of innovation, its radicalness and the kinds of investments dedicated to support its development, are likely to have specific effect on firms' human resources and their variation over time.

The survey also provides the firm's number of employees at the beginning and end of the three years reference period. However, the harmonized questionnaire set-up by Eurostat does not include any information regarding employees' skills. Fortunately, a few countries, including Luxembourg, have included information regarding the proportion of employees by level of formal education. Another important limit of that survey is that only the full stock of employees on both dates is available. No information is provided regarding a firm's recruitment of new employees and therefore the volume of such recruitment and the skills of these employees. Nor does the survey provide any detailed information regarding the evolution of firm's human resources over time with respect to the launch of a firm's innovation activity. The lack of such information has to be taken into account when linking firms' innovation activity and its induced employment variation. It is indeed assumed that, to complete the setting of new or updated technologies, firms may choose between hiring new employees or training the incumbent ones (Bauer and Bender 2004). In case the adoption costs are higher relative to the job creation costs, firms are also assumed to destroy the old jobs and to hire new workers with the necessary skills to work with the new technology and/or the new organizational environment (Mortensen and Pissarides 1998). An additional restriction related to this survey is its coverage. While manufacturing firms and firms involved in business services take part in this survey, some other services, and among them personal services, are not surveyed, reducing the opportunities to adequately examine biased technological change (see 5.2). Small firms with less than ten employees are also excluded, hampering the examination of creative destruction (Schumpeter 1942).

5.1.b. Empirical evidence derived from innovation surveys

Innovations are assumed to have intra-firm or direct effects on the innovating firms and inter-firm or indirect effects on other players. Firm-level analyses focus on the former, while aggregate analyses on the latter. For the former, to which this sub-section is dedicated, varying effects on the employment of innovating firms are reported by the literature. A usual distinction is made between displacement and compensation effects on firm-level employment induced by product and process innovation (see Figure1.1). Compensation effects are defined according to the elasticity of employment with respect to the demand for labour following the introduction of innovation. Displacement effects relate to the specific effect of innovation on a firm's demand.

Basically, process innovation is likely to support a firm's employment positively or negatively. Even if process innovation is assumed to increase firm productivity, such improvement may result either from labour-saving adjustments (through displacement effects), and therefore job reductions, or cost reductions, passed on in a firm's price and supporting a firm's success on the product market (through compensation effects) and therefore job increases. Product innovations are more clearly expected to support a firm's employment growth. However, the development of new products using less labour input (thanks to displacement effects) may also have a negative impact on a firm's employment.

Figure 1-1: Firm-level employment effect of product and process innovations on innovating firms

	Displacement	**Compensation**
Process innovation	Productivity or labour saving effect (-)	Cost reduction passed on price (+)
Product innovation	New product requiring different or less labour input (+/-)	Increasing demand (+)

Source: Harrison *et al.* 2014.

A recent contribution has set-up a structural model based on firm-level CIS data. This model is dedicated to examining the effect of at least one product and process innovation on employment growth, with employment growth as a firm's outcome (Harrison *et al*. 2014). It aims, amongst other things, to control for potential reverse causality between innovation and employment. In their original model Harrison *et al*. (2014) decompose employment growth into the following four components: y_1 the rate of growth of old products, y_2 the rate of growth of new products, *d* the introduction of process innovation and *u* an overall random disturbance.

$$l = \alpha_0 + \alpha_1 d + y_1 + \beta y_2 + u \text{ (I.1.0)}$$

Based on this equation, employment growth can be impacted by: i) the average efficiency growth of the production of old products (α_0 for non-process innovators and α_1 for process innovators); ii) the growth rate of old products (y_1); iii) the relative impact of new products (β); and iv) the real output growth due to new products (y_2). It should be noted that the y_1 coefficient is set equal to 1 in their original model, (corresponding to long-term expectations, see Basu *et al.* 2005), leading to putting to the fore the following three remaining parameters: α_0 representing the average efficiency growth in the production of old products, α_1 the process innovation effect (in case d=1), and β the relative efficiency of the production of new products.

However, as highlighted by Harrison *et al.* (2014), two main issues have to be solved for the estimation of this basic model. The first issue relates to the estimation of the relative efficiency of producing old and new products. To solve this, growth in nominal sales needs to be substituted by growth in real production. As a firm's price is not available, corresponding industry price indices π are used as a proxy[5] . In addition, (l − (g1 − π)) is used as the dependent variable, so as to identify an effect of process innovation on employment net of (direct) compensating price variations. The second issue relates to an endogeneity problem due to the possible correlation of y2 with productivity shock. So as to solve this, appropriate instruments, uncorrelated with the price difference and the productivity shock, need to be found. Basically, Harrison *et al.* (2014), take advantage of a specific question in the CIS questionnaire dealing with the objective of product innovation to build instrument variables.

The reference model becomes:

$$l - (g_1 - \tilde{\pi}_1) = \alpha_1 pc + \beta g_2 + v \quad \text{(I.1.1)}$$

With:

$g_1 = y_1 + \pi_1$	*: Nominal output rate due to old products, i.e. net sales growth due to old products*
$g_2 = y_2 + \pi_2 y_2$	*: Nominal output rate due to new products, i.e. net sales growth due to new products in the period*
π_1	*: Price growth rate of old products at the firm level*
$\tilde{\pi}_1$	*: Price growth rate of old products at the industry level*[6]
$v = -E(\pi_1 - \tilde{\pi}_1) - \beta\pi_2 y_2 + u$	*: Price difference between new and old product in relation to the price of the old product*

This model, or slight variations of it, has already been applied using country data-sets (*e.g.* Hall *et al*. 2008, Zuniga and Crespi 2013, Dachs and Peters 2014). The empirical evidence deriving from these applications is the following. Firstly, product innovation mainly supports employment growth. However, in most cases, product innovation appears to enhance labour productivity too ($\widehat{\beta(g_2})$ <1), reducing the positive impact of sales growth from new products. The marginal effect of sales growth from new products is as such lower than the one of the old products. In addition, process innovation appears usually to induce either a negative or not significant employment growth in line with a labour-saving effect usually assumed for this kind of innovation.

[5] Industry price indices used derive from the OECD STAN database for industrial analysis. Data was extracted in April 2013.

[6] As firm level prices are not available in the CIS data, corresponding industry price indices ($\tilde{\pi}_1$) extracting form the STAN OECD output deflator database are used as proxies. In order to account for the fact that 45% of firm in our database evolve mainly on foreign markets, industry price indices calculated at the OECD level are assigned to those firms, while industry price indices calculated at the local level are assigned to others. This allows to take into consideration, at least partly, the impact of being active on international markets (Klein *et al.* 2003).

Dachs and Peters (2014) complete these findings by focusing on firms according to their ownership. Firms belonging to a group, and especially a foreign one, are expected to be more inclined to offshore part of their production to low wage countries, notably the production aspects involving routinized tasks. Their results support this claim, as foreign-owned firms experience lower local employment growth than domestically owned firms.

It should, however, still be stressed that there are limitations imposed on this model by the coverage of the standard CIS surveys and the restricted information regarding a firm's employees collected by them (see 5.1.a. for more details). As firms with less than ten employees are excluded, any analysis of the creation/destruction process through innovation activities are restricted. It has to be noted that such analysis would also require paying great attention to firms' demography across the surveys waves, and therefore should match constitutive surveys at firm level. Moreover, in order that such matching can provide significant insights, a large share of firms have to take part in at least two successive waves, or, more basically, a panel sampling frame has to be used for the survey data collection. Therefore, instead of focusing on creation/destruction, one may focus on the firm-level cannibalization, *i.e.* the compensation mechanism within a given innovative firm between old and new products. The compensation and displacement mechanisms at the aggregate level with competitors or suppliers is also narrowed by sample size and economic activity selection derived from the survey sampling frame. The non-coverage of firms involved in personal services further hampers any examination of employment polarization (see 5.2). For the skill-biased examination, one has to focus on the data-set derived from only a few countries, mainly from South America, in which firm-level employment according to skills was collected. Based on this data, one can examine whether innovation activity sustains more high-skilled than low-skilled employment, as suggested by the biased technological change literature (see 5.2).

Among the few papers taking advantage of this extended dataset, two specifically focus on this point. One is based on Uruguayan service firms (Aboal *et al*. 2015), while another one is focused on manufacturing firms from Argentina (de Elejalde *et al*. 2015). The empirical results of Aboal *et al*. (2015) support a positive and significant impact of new products for both skilled and unskilled employment ($\widehat{\beta(g_2)}$ >0). However, unskilled employment is supported by a clear productivity effect restraining its growth ($\widehat{\beta(g_2)}$ <1). Such an effect is not found for skilled employees. This finding is therefore rather in line with a specific skills bias induced by product innovation with lower employment perspectives for unskilled employees.

The empirical evidence of De Elejalde *et al*. (2015) differs slightly. First of all, in addition to positive support of new products to employment growth ($\widehat{\beta(g_2)}$>0), a reverse productivity effect ($\widehat{\beta(g_2)}$ >1) stands out for skilled workers. Basically, a given change in new sales growth supports a higher change in skilled employees. Such an effect is not found for unskilled workers insofar as we do not focus on high-tech sectors. Those results therefore also support the skilled biased effect of product innovation, but with better perspectives for skilled employees rather than lower opportunities for the unskilled employees. Unfortunately, as these two country results, which differ slightly, derive from different sectors, the manufacturing sector vs the services sector, the respective country and sector contribution remains to be disentangled. Additional insights from other Latin America countries would be welcomed for that purpose.

Moreover, even if many restrictions are imposed by the data-sets at hand, Harrison *et al*. (2014) provide an employment growth decomposition in order to disentangle the compensation and displacement effects at work between the firms taking part in the survey and therefore the target population of the survey. Such structural decomposition combine the estimated parameters derived from the structural model $[\hat{\alpha}_0, \hat{\alpha}_{0j}, \hat{\alpha}_1, \hat{\beta}]$ with descriptive results $[ind_j, pc, g_1, g_2]$, a firm's choice to introduce product innovation $[I(g_2 > 0)]$ and estimation of price variations that firms have to face $[\tilde{\pi}_1]$.

$$l = \underbrace{\textstyle\sum_j(\hat{\alpha}_0 + \hat{\alpha}_{0j})ind_j}_{1} + \underbrace{\hat{\alpha}_1 pc}_{2} + \underbrace{[1 - I(g_2 > 0)](g_1 - \tilde{\pi}_1)}_{3} + \underbrace{I(g_2 > 0)\left(g_1 - \tilde{\pi}_1 + \hat{\beta} g_2\right)}_{4} + \hat{\upsilon} \quad \text{(I. 1.2)}$$

1. The first term reflects the change in employment related to general industry (α_{0j}) and overall productivity growth (α_0) in the production of old products (i.e. not innovative products).

2. The second term corresponds to the net employment contribution from process innovations in the production of old products.

3. The third term measures the employment change associated with output growth of old products for firms not introducing any new products.

4. The fourth term synthesizes the net contribution of product innovation to employment for product innovators, including the potential cannibalization of old products by new ones.

The final term is the residual term (zero, on average).

Finally, it has to be highlighted that additional issues have to be overcome when including a local level of analysis in such a model. The inclusion of local level requires first to augment the model in order to take into account external economies fostered by local competition and local variety or specialization. The focus on local level also requires to further augment the model in order control for potential confounding factors that may operate at this level, as firms' characteristics are not random across space. However, such augmentation is likely to induce a multicollinearity issue between the location variable(s) and the additional firm's level characteristics introduced in the model.

It would also be very interesting to examine what happens during a downturn. Basically, does the compensation phenomenon take place during such a time? Three additional issues have to be considered in that case. Firstly, the shock that firms have to face in different local labour markets is not random as the average firm can belong to rather different industries. Secondly, firms' involvement in innovation may be increasingly endogenous, as a firm may choose to modify its involvement in innovation activity to face this downturn situation. Thirdly, a firm's success on the product market has to be taken into account in employment adjustment. Indeed, those still successful on the product market are likely to take advantage of additional labour resources at the lower cost induced by the shock. Conversely, those less successful on the product market may not fully readjust their skilled human resources downwards during a downturn, in line with a transaction cost perspective.

5.2. Biased technological change

The basic hypothesis of skill-biased technological change relates to differences in outcome for skilled employees induced by technological change. The outcome may be job and/or wages opportunities, while such a differential is induced by either a greater demand for skills in new technologies and/or by the higher complementarity of these technologies with skilled workers. One should, however, note that the supply of high-skilled workers has also increased, leading to the Tinbergen race between technology and the supply of skills (1974, 1975). These biased opportunities also generate potential inequality issues that may increase over time. A first point deals with skill-biased technological change, while a second one extend the analysis to employment and wage polarization.

5.2.a Skill biased technological change

The canonical model of skill-biased technological change makes a distinction between two types of workers, *i.e.* high vs low-skilled. These two types are used as two factors. In empirical applications, skills are in most cases based on education, high-skilled usually corresponding to university graduate workers, and low-skilled to high school graduate workers. However, some scholars also use the ISCO classification to derive these two factors.

These two factors, high and low-skilled workers, are assumed to be imperfect substitutes through the constant elasticity of substitution. Technologies are modelled as factor-augmenting labour, by increasing through learning by doing (see 2.0) the productivity of the high and/or low-skilled. This model treats technology as exogenous, by not assuming that individuals may adapt their supply of skills or that firms may adjust their demand for skills according to the situation that they have to face. The setting of the two types of wages is also assumed to derive from competitive markets and therefore to equal the value of their marginal product.

The following formal model addressing skill-biased technological change is derived from Acemoglu and Autor (2011).

The production function of the overall economy is the following, with σ as the elasticity of substitution between high and low-skilled workers.

$$Y = \left[(A_L L)^{\sigma-1/\sigma} + (A_H H)^{\sigma-1/\sigma}\right]^{\sigma/\sigma-1} \text{ (I.2.1)}$$

The low-skilled unit wage is determined by the value of the marginal product of low-skilled labour, derived from the differentiation of 2.1.

$$w_L = \frac{\partial Y}{\partial L} = A_L^{\sigma-1/\sigma}\left[A_L^{\sigma-1/\sigma} + A_H^{\sigma-1/\sigma}(H/L)^{\sigma-1/\sigma}\right]^{1/\sigma-1} \text{ (I.2.2)}$$

The high-skilled unit wage follows the same rule.

$$w_H = \frac{\partial Y}{\partial H} = A_H^{\sigma-1/\sigma}\left[A_L^{\sigma-1/\sigma}(H/L)^{-\sigma-1/\sigma} + A_H^{\sigma-1/\sigma}\right]^{1/\sigma-1} \text{ (I.2.3)}$$

The wage premium can be set up as the combination of 2.2 and 2.3.

$$w = \frac{w_H}{w_L} = \left(\frac{A_H}{A_L}\right)^{\sigma-1/\sigma} \left(\frac{H}{L}\right)^{-1/\sigma} \text{ (I.2.4)}$$

The wage premium can be rewritten in log, showing its key dependence on the relative supply of skill H/L and the relative technology term A_H/A_L.

$$\ln w = \frac{\sigma-1}{\sigma} \ln \left(\frac{A_H}{A_L}\right) - \frac{1}{\sigma}\left(\frac{H}{L}\right) \text{ (I.2.5)}$$

Differentiating (I.2.5) with respect to H/L highlights that, for a given skill bias of technology (A_H/A_L), any increase in the supply of skills decreases the skill premium by 1/σ

$$\frac{\partial lnw}{\partial lnH/L} = -\frac{1}{\sigma} \quad \text{(I.2.6)}$$

Differentiating (I.2.5) with respect to A_H/A_L provides the following result.

$$\frac{\partial lnw}{\partial \ln(A_H/A_L)} = -\frac{\sigma-1}{\sigma} \quad \text{(I.2.7)}$$

One may assume σ>1, implying that any improvement in the high-skill augmenting technology fosters the skill premium.

However, as A_H/A_L cannot be observed, one may derive it, assuming a log-linear increase in the demand for skill over time coming from technology.

$$ln\left(\frac{A_{H,t}}{A_{L,t}}\right) = \gamma_0 + y_{1,t} \quad \text{(I.2.8)}$$

Substituting (2.8) in the key equation (2.5) leads to the following equation (I.2.9), providing a way to empirically estimate, in (2.10), the two following key parameters, $\sigma\ [= 1/0.61]$ as the elasticity of substitution between high and low-skilled workers, and $(\sigma - 1)/\sigma$ as the annual increase of relative demand for university labour.

$$lnw_t = \frac{\sigma-1}{\sigma}\gamma_0 + \frac{\sigma-1}{\sigma}\gamma_{1,t} - \frac{1}{\sigma} ln\left(\frac{H_t}{L_t}\right) \quad \text{(I.2.9)}$$

$$ln\ w_t = constant + 0.027 * t - 0.612 * ln\left(\frac{H_t}{L_t}\right) \text{ (I.2.10)}$$

The estimations derived from the application (I.2.9) with US data from 1963 to 1992 shows that the elasticity of substitution between college graduate workers and non-college graduate workers is about 1.6 (=1/0.61) and that the annual increase in relative demand for university labour is about 2.7 percent. These estimations are rather in line with empirical evidence. However, after 1992 there is a clear divergence from the previous estimates and, more importantly, between the estimates deriving from the model and the empirical evidence (Acemoglu and Autor 2011). These estimates suggest, either increasing elasticity of substitution between types of skills, or a slower demand growth trend for university workers, both leading to an overestimation of the rise in the university premium. Such a shift may be due to at least three factors. The first one relates to the increasing impact of some potential confounding factors over time, such as trading opportunities with emerging countries like China. It may equally be due to the increasing substitutability of some tasks in which employees are involved by capital (see 5.2.b). Finally, one may notice the limitation imposed by the treatment of technological change as exogenous in this canonical model, on the side of both the skill supply and the skill demand. The former argument is further examined in the following paragraph, while the latter one is postponed to the next one.

In line with the Tinbergen race between demand for skills, induced by technological change, and the relative variation in the supply of skills, one may assume that workers are able modify the type of skills they offer to the market in response to either technological change or the availability of factors on the market. The introduction of endogenous choice deriving from the labour market may thus provide a way of explaining historical variations. Among the sources of endogenous skills choice, some scholars have focused on skill supply (Acemoglu and Autor 2011, Dupuy 2015), while some others on formal education (Ábrahám 2008).

Technology adoption (or the demand side) may also be assumed as endogenous. According to Beaudry *et al.* (2010) the speed and extent of technology adoption vary according to the local comparative advantages. Areas with low relative prices or a high relative supply of skilled workers are therefore more likely to adopt new technologies due to their complementarity with these jobs providing a higher return for skills. More generally, the process of skill-biased technical change, and therefore the degree to which innovation would complement skilled workers, may vary over time (Acemoglu and Autor 2011). In the extreme case, skilled workers would be replaced rather than complemented by technological change. According to this perspective, and focusing on the recent trend, one would have to examine whether recent technological change driven by computer technology may have shifted the process of skill-biased technical change.

5.2.b Skill-biased versus polarisation

Jobs and wages polarization assumes the specific role of service occupations. According to Autor and Dorn (2013a) polarization is induced by the interaction of two forces, (1) consumer preferences, assuming that variety is preferred over specialization, and (2) non-neutral technological change, the latter reducing the costs of routinized tasks. Defined as such, both these forces sustain the increasing demand for service jobs without clear substitutes and therefore favour employment, and potentially even wages, in these occupations. The exclusion of the changes to occupations that are intensive in terms of well-defined procedures, usually found in the middle of the skill and wage distribution, leads to the so-called polarization of employment and wages.

Autor and Dorn provide (2013a) a formal model for skill-bias vs polarization in employment and wages. Three focal cases are derived from this model, *i.e.* employment polarization, wage and employment polarization, and standard skill-bias. The allocation of low-skilled labour between services using manual, non-routine tasks and goods using routine tasks is assumed to result from three key parameters: the elasticity of consumption between goods and services (σ=1/(1-ρ)), the elasticity of production between computer capital and routine labour (1/(1-μ)), and the share of routine tasks as input in the production function (β).

The following production function combining cognitive and routine labour is set with α_r and α_k as efficiency parameters.

$$Y_g = L_c^{1-\beta}[(\alpha_r L_r)^\mu + (\alpha_k K)^\mu]^{\beta/\mu} \quad \text{(I.3.1)}$$

As the service sector only includes non-manual workers, only non-routinized tasks are performed in the service sector.

$$Y_s = \alpha_m + L_m \quad \text{(I.3.2)}$$

Consumers and workers have the following identical CES utility function for goods and services.

$u = (c_s^p + c_g^p)^{1/p}$ (I.3.3)

The price of computer capital is assumed to tend towards zero leaving the allocation of low-skilled workers between non-routine and manual tasks to be determined by the elasticity of consumption between goods and services ($\sigma = 1/(1-\rho)$), the elasticity of production between computer capital and routine labour ($1/(1-\mu)$) and the share of routine tasks as an input in the production function (β). w_m/w_r are set as the relative wage dedicated to manual vs routine tasks and wc/wr as the relative wage for non-routine cognitive vs routine tasks.

$$\bar{L}_m = \begin{cases} 1 & if\ \frac{1}{\sigma} > \frac{\beta - \mu}{\beta} \\ \bar{L}_m \epsilon (0,1) & if\ \frac{1}{\sigma} = \frac{\beta - \mu}{\beta} \\ 0 & if\ \frac{1}{\sigma} < \frac{\beta - \mu}{\beta} \end{cases} \quad \text{(I.3.4)}$$

$$\frac{w_m}{w_r} = \begin{cases} \infty & if\ \frac{1}{\sigma} > \frac{\beta - \mu}{\beta} \\ -\log(1 - L_m^*) & if\ \frac{1}{\sigma} = \frac{\beta - \mu}{\beta} \\ 0 & if\ \frac{1}{\sigma} < \frac{\beta - \mu}{\beta} \end{cases} \quad \text{(I.3.5)}$$

$$\frac{w_c}{w_m} = \begin{cases} 0 & if\ \sigma < 1 \\ 1 & if\ \sigma = 1 \\ \infty & if\ \sigma > 1 \end{cases} \quad when\ \frac{1}{\sigma} > \frac{\beta-\mu}{\beta} \quad \text{(I.3.6)}$$

Equations (3.4) are dedicated to employment polarization, while (3.5) and (3.6) to wage polarization. In order to ease the employment polarization examination (3.4), β may be set to 1, leading every worker being employed in the manufacturing sector to perform routine tasks. As such, a comparison only has to be made between $1/\sigma$ vs $1/\sigma_r$ and two trivial cases remain:

- if $1/\sigma > 1/\sigma_r$ *i.e.* If $\sigma < \sigma_r$ then LM=1
- if $1/\sigma < 1/\sigma_r$ *i.e.* If $\sigma > \sigma_r$ then LM=0

In the first case, the production elasticity between computer capital and routine labour is greater than the consumption elasticity between goods and services. This leads low-skilled workers to be displaced to the service sector for performing manual tasks (technological progress inducing a decrease in computing costs raises the demand for service employment). Job polarization therefore arises. Reintroducing β, and assuming that workers may be involved in cognitive tasks in the manufacturing sector, the condition becomes: $1/\sigma > (\beta - \mu)/\beta$.

In the second case, the production elasticity is lower than the consumption elasticity. Low-skilled workers are then hired in the goods sector in order to perform the routine tasks. This result is in line with the monotone skill-biased setting from the canonical model. Reintroducing β, the condition becomes: $1/\sigma < (\beta - \mu)/\beta$

The polarization of jobs is a necessary but not sufficient condition for wage polarization. In order for the polarization to occur, two additional conditions are needed, one in (I.3.5): $w_m > w_r$; and one in (I.3.6): $w_c <= w_m$. Basically, the wages of manual tasks have to increase with respect to the wages of routinized tasks, while the wages of manual tasks do not have to decrease with respect to the wages of cognitive tasks. In order to do so, goods and services also have to have gross complementary, *i.e.* $\sigma < 1$.

Empirical evidence in line with wage or job polarization has been provided, not only for the US, but also for the UK and as well as for the main EU countries (Goos *et al*. 2009). More recent empirical investigations enlarge their scope so as to overcome the bias that may be induced by potential confounding factors such as offshoring (Van Reenen 2011, Goos *et al*. 2014). Autor (2013) provides, in addition, an overview of the challenges that the “task approach” have to face, stressing that empirical studies have to be replicated according to shared and standardized sets of task measures.

Indeed, different potential confounding factors have been highlighted for employment/wage polarization. The challenge being to control for the potential effect of these factors that may be unobserved and correlated with both job tasks and the random disturbance. These refer mainly to two main kinds of change over time. The first one is the increasing international competition for manufactured products leading to the offshoring of jobs to low-wage countries (Autor *et al.* 2013b, Acemoglu and Autor 2011, Acemoglu *et al*. 2015, Grossman and Rossi-Hansberg 2008, Goos *et al.* 2014).

The second argument relates to institutional changes at the country level. According to some scholars de-unionisation (Firpo *et al*. 2011, Kok *et al*. 2013) has decreased the bargaining power of blue collar workers, while for some others the unfavourable situation of low-skilled workers results from the decrease in the real value of the minimum wage (Card and DiNardo 2002, Lemieux 2006). In addition to these two main arguments, some also highlight the potential effect of an unfavourable business environment, manufacturing jobs being more affected by adverse business cycles (Foote *et al*. 2014), while some focus on the specificity of recent technological change, arguing that they induce a lower return to employment growth and especially for routinized tasks (Debonneuil and Encaoua 2014).

5.3 Adjustment mechanisms at aggregated level

The focus on adjustment mechanisms shifts the focal point from firm-level analyses to sectors, local areas (local multiplier effect) or even the overall economy (nationwide multiplier). Any shock at micro-level may have indirect effects on other players and therefore at other levels of analysis. Different kinds of shocks may also be considered. While a first paragraph deals with changes at different levels of analysis, a second one focus on agglomerations effects, a third one on neighbouring effects and a fourth one on multiplier effects.

5.3.a The impact of Technical change at aggregated level

In addition to a direct effect on innovating firms, innovation may have an indirect effect at various levels, *i.e.* the sectoral, local and national level. The examination of those levels, combined with the direct effect of innovation examined previously, provides insights regarding the net effect of innovation.

The sectoral level is assumed to focus the analysis on specific regimes (Antonucci 2007) due to the relative homogeneity of the players at this level. Such homogeneity provides, in addition, a way of identifying a large part of product substitution and differentiation, including business-stealing effects[7], and therefore the main part of the indirect effect of product innovation (Mastrostefano and Pianta 2009). Such an indirect effect of product innovation is, however, ambiguous as new products

[7] The business-stealing effect relates to the decreasing sales of incumbent firms generated by a new entrant on the market. Such new entrant "steals business" from incumbent firms.

favouring employment of the innovating firms are assumed to cannibalize the old products of non-innovating competitors inducing a labour-saving effect for them. The main indirect effect of process innovation derives, in a competitive setting, from price variations expected to decrease, at least for pure process innovations, thus favouring lower costs and higher demand. The overall effect depends therefore on the price elasticity of demand likely to compensate for the expected negative direct effect of process innovation (Verspagen 2004). Such an overall effect is also likely to cross the boundaries of the sector due to input-output relations across sectors. Two additional externalities likely to cross the sectoral boundaries may arise as well. The first one is knowledge spillovers enhancing opportunities for other firms, including competitors, as far as knowledge would not be fully appropriated nor protected by formal methods (*e.g.* patents). The second one is complementarity with the other products/components of other firms and increasing customers' appeal for the latter and therefore also potential demand.

The local level offers an additional way of examining the indirect effects of innovation. It provides, firstly, a way to examine effects that cross industry borders without focusing on the overall economy (see the multiplier effects below). Local areas are indeed more specialized in some industries than an overall economy and close proximity enhances the potential complementarity between firms and sectors through so-called agglomeration effects (see below). In addition, market entry and exit induced by a creative destruction process are expected to be strengthened in more knowledge-intensive areas, complemented by a relocation across areas along firms' product life cycle (see Duranton and Puga 2001). Specific local regimes deriving from spatial life-cycle model and determined by the maturity of a given place's industry structure are therefore likely to be observed across local areas (Audretsch *et al*. 2008).

A macro-perspective is dedicated to focusing on the impact of national regulations, including non-market factors derived from labour market rules. It further provides a way of introducing social and economic conditions sustained by national technological commitments into the analysis, and a specific literature has flourished for this (see the so-called national system of innovation). As those components are assumed to have their own effects on employment growth, they are likely to confound the skill-biased technological change. Indeed, institutional factors may impact employment growth across countries, by (dis)advantaging employment and wages of individuals with specific skills or involved in specific tasks (see 5.2.b. discussion among other on the potential effect of confounding factors in the employment/wage polarization). At this level of analysis, many aspects may interplay. The successful inclusion of these different components, may, therefore, provide a way of examining the net effect of technological change on employment. However, the identification of this net effect may necessitate the overlay of data by different levels of analysis (firm/sector/place/country).

5.3.b. Agglomeration effects

Agglomeration effects have been introduced previously (see 3). The aim of this subsection is to focus on recent developments with respect to their effect on employment growth. Firms basically have to face the trade-off between agglomeration advantages and agglomeration disadvantages. Agglomeration effects are assumed to also foster firm productivity and to increase the cost of business premises through a general equilibrium effect. As such, agglomeration effects are assumed to enhance labour-saving effects. Putting all this together, the overall effect of agglomeration on employment growth seems ambiguous.

According to Beaudry and Schiffauerova (2009), providing a meta-analysis of agglomeration economies, a clear distinction has to be made between studies focusing on productivity growth and those based on employment growth as the dependent variable. Firstly, individual jobs may be complemented or substituted by product or process innovation. Secondly, innovation is assumed to be skills-biased, meaning that employment is non-homogeneous and a specific shock is assumed to have varying effects on workers with different skills (see the skills-bias earlier). In addition, worker mobility and the substitution of labour by capital, which both appear as adjustment mechanisms, vary greatly according to skill. Examining the effect of any shock on employment and productivity, both potential proxies for economic growth, is therefore likely to provide divergent results. In line with these arguments, Cingano and Schivardi (2004) show that using alternatively employment or productivity growth as a dependent variable may lead to opposite results for the MAR externality.

However, due to restricted data availability, many scholars who use local units or industries across regions as the dependent variable, still use employment variation as a proxy for growth. Access to firm-level data, which usually provides some fine-grained measures of output such as value added or turnover, has to be favoured. This level of aggregation may also provide additional parameters, in a more exogenous way and with lower multicollinearity. Other factors are indeed expected to impact growth. Following this line, different scholars have suggested extending the control for externalities. Among them, Frenken *et al*. (2005) have introduced related and unrelated variety, while Combes and Labourcade (2012b) have focused on the identification of local concentration through three additional parameters: *i.e.* local density, superficy, and market potential.

Moreover, in addition to an overall impact on employment growth, on which two seminal papers (Glaeser *et al*. 1992 and Henderson *et al*. 1995) have focused, the relative importance of the three standard components of agglomeration effects, namely the Marshall-Arrow-Romer, Jacobs and Porter externalities may favour employment growth through skills in a different way. However, employer-employee data seems needed for such an examination. In every case, specific attention has to be paid to the spatial dimension in which the economic phenomenon takes place and induces agglomeration effects. Recent studies on labour market dynamics are focused on local labour markets, corresponding to functional regions and defined according to commuters' behaviour. Adjustments across such labour markets are assumed through the mobility of firms and workers (especially high-skilled) and adjustments on the land market, thus increasing the request for micro-based data.

In order to go further in the identification of agglomeration parameters, agglomeration economies have to be modelled jointly with the industrial structure (Cingano and Schivardi 2004). Structural forms models (instead of reduced form) may be used for that purpose, taking advantage of the (new) theoretical results from economic geography (see Krugman 1998, Ottaviano and Thisse 2004, Fujita and Krugman 2003). Using such an approach, Combes *et al*. (2004) makes a distinction between the impact of existing firms and newcomers on employment growth. Blien *et al*. (2006) highlight the timing impact on employment growth of diversity, specialization and the local human capital structure. Dauth (2010) focus on the impact of co-located industries on the components of the Marshall forces supporting employment growth.

5.3.c. Neighbouring effects

Three main challenges have been stressed as having to be overcome in order to identify neighbouring or network effects (Bramoullé *et al*. 2009, Boucher *et al*. 2014). The first one is to define the reference group in which peer effects might occur. The second one relates to methodological and econometric issues to be overcome. The third one is the reflection issue.

The first challenge is to define the reference group in which exchanges with peers may occur. The basic question is, therefore, who interacts with whom? Economic theory provides different insights regarding such a question. *E.g.* according to MAR externalities interactions take place within a given sector, while for Jacobs externalities arise across “related” sectors. The precise set-up of the interactions is at the root of different connected fields, *i.e.* “neighbouring effects” and “network effects”. In the first case, interactions taking place across specific locations are put to the fore, leading to place-based networks, while in the second one interactions are more abstract. Both cases usually face information issues due to partial knowledge of the basic elements around which interactions take place and the characteristics and behaviour of the players interacting.

The second challenge refers to identification issues. Insofar as the network is well defined and observable, even by proxies, potential confounding factors have to be taken into account. In addition, endogeneity of network formation, or for the place-based networks the endogeneity of firms’ location, also have to be considered. For the latter case, one may use as instrument strategy the shift-share approach of Bartick (1991), controlling in addition for sorting with additional fixed effects at higher levels. Moreover, a correlation between unobservables is a common issue induced by the use of aggregated data. Spatial econometric techniques usually focus on this issue, through *e.g.* Spatial Error Model (SEM) or Spatial AutoRegressive model (SAR). However, other strategies may be followed using either a specific research design or the econometric tool-box, as we will see hereafter.

The third challenge is about the reflection problem (Manski 1993) or the simultaneity issue (Moffit 2001) arising when one wishes to examine whether the average behaviour in a given group has any impact on the behaviour of the individuals belonging to that group. Basically, two issues have to be solved. The first one is to be able to identify the endogenous effect ($\bar{Y}$) from the exogenous or contextual effect ($\bar{X}$). The second one is to identify social interactions, including both endogenous and exogenous effects, from the correlated effects. For the latter case, the environment that individuals have to face has to be controlled in the empirical analysis. In case those issues are adequately solved, one may focus one's attention on the social multiplier effects $\left[\frac{1}{1-\bar{Y}}\right]$ computed from the endogenous effect ($\bar{Y}$).

Two recent solutions have been suggested for solving the reflection issue. A first one, provided by Bayer *et al*. (2008), is derived from a specific research design in which individuals' location is sampled for very small areas (*i.e.* the census block group defined by the US census bureau). At this level, it is assumed that individuals are unlikely to precisely choose their neighbours, leading to assume that the setting up of the neighbouring environment is exogenous. Bayer *et al.* (2008) provide empirical evidence for that claim, showing that individual characteristics are not correlated within such areas. In addition, both the endogenous ($\bar{Y}$) and exogenous ($\bar{X}$) effects are controlled simultaneously. In addition, one may control for endogenous spatial sorting at a higher level through an instrumentation strategy using, *e.g.* a shift-share strategy (Bartik 1991). However, such research design appears more adequate for the examination of social issues related to the place of residence of individuals than for spillovers effects that derive from firms' location. Indeed, the exogneity of the neighbouring environment remains to be checked for firms even at this narrow level. This research design is also better fitted to examine individual-level employment status than employment growth. Our formal model will, therefore, be focused on employment status.

$$EMP_{ijt} = \alpha + \beta\bar{Y}_{jt} + \eta\bar{X}_{jt} + \gamma X_{it} + \phi_g + \phi_t + \varepsilon_{ij} \quad \text{(I.4.0)}$$

With:

EMP_{ijt} *as employment status of individual i in area j in time t*

$\beta(\bar{Y}_{jt})$ *as the endogenous effect among the dependent variable from other firm belonging to the area j in t*

$\eta(\bar{X}_{jt})$ *as the exogenous effect among the independent variables from other firm belonging to the area j in t*

$\gamma(X_{it})$ *as the direct effect from firm's individual characteristics*

ϕ_g *as a fixed spatial effect*

ϕ_t *as a fixed time effect*

ε_{ij} *as the unobserved random component*

Lee (2007) provides a more general strategy for the linear in-means model in which the outcome of each individual (firm in our case) depends linearly on his own characteristics, the mean outcome of his reference group and the mean characteristics on its group. Such strategy may be more adequate for examining spillover effects in term of linear employment growth. Basically, as a first step, he applies a within transformation so as to remove unobserved random disturbance from the equation, thus dropping any potential correlation between this term and the endogenous or exogenous effects. In a second step, he estimates the transformed model by either Conditional maximum likelihood (CML) or generalized two-stage least squares (Generalized 2sls) in order to solve the reflection issue. Assuming sufficient variations in group sizes[8], this strategy seems to provide the most convenient solution for examining the impact of external economies and spillovers. Amara and El Lahga (2015) have recently followed this strategy in order to identify the neighbouring effects on the performance of Tunisian manufacturing firms. In addition, they consider different reference groups in their setting up of the neighbouring environment, in line with the basic assumption related to either high interaction within a given sector (MAR externalities) or between "related" sectors (Jacobs externalities).

[8] Davezies *et al.* 2009 show that this model is generally identified when at least three different sizes of peer groups are observed in the empirical sample.

$$y_{ri} = \alpha_r + \beta \bar{y}_{-i} + \gamma x_{ri} + \delta \bar{x}_{-i} + \varepsilon_{ri} \quad \text{(I.5.0)}$$

With:

$\beta(\bar{y}_{-i})$ *as the endogenous effect among the dependent variable from the n-1 other firms*

$\delta(\bar{x}_{-i})$ *as the exogenous effect from the n-1 other firms*

$\gamma(x_{ri})$ *as the direct effect from firm's individual characteristics*

ε_{ri} *as the unobserved random component*

Spatial econometrics aiming to integrate up to three different types of interactions as a modelling strategy can also be used to solve the reflection issue and the other challenges. A full model, including all these interactions, takes the following form:

$$Y = \delta \boldsymbol{W} Y + \alpha i_N + \beta X + \theta \boldsymbol{W} X + \mu \quad \text{(I.6.0)} \qquad with\ \mu = \lambda \boldsymbol{W} u + \varepsilon$$

With:

$\boldsymbol{W}$ *as the weight matrix*

$\delta(\boldsymbol{W}Y)$ *as the endogenous interaction effects among the dependent variable*

$\theta(\boldsymbol{W}X)$ *as the exogenous interaction effects among the independent variables*

αi_N *as the constant term*

$\beta(X)$ *as the direct effect from firm's individual characteristics*

$\lambda(\boldsymbol{W}u)$ *as the interaction effects between the disturbance term of the different units.*

ε *as the unobserved random component*

Three main reduced forms of this model, the Spatial AutoRegressive model (SAR), the Spatial Error Model (SEM) and a combination of both, *i.e.* the Spatial Durbin Model (SDM), are often applied. These aim to control for the bias induced by the correlated disturbance term between the different units. Based on the two additional types of interaction, a usual distinction is made between direct and indirect effect (Elhorst 2014). SEM only includes direct effects (X) in its setting, while SAR model includes both direct and indirect effects $(X, \bar{Y})$. Only the Spatial lag model, Spatial Durbin model or Sac model (Kelejian and Prucha 1998) go further, in line with the distinction between endogenous and contextual effects. Such extensions are needed when one wishes to focus empirically on the potential impact of knowledge spillovers and local externalities

Spatial econometrics models may be estimated using similar models as the one stressed by Lee (2007) *i.e.* generalized, two-stage least square (Kelejian and Prucha 1998) or methods using maximum likelihood. However, one recurrent criticism of this overall modelling strategy is about the setting up of the spatial weights matrix. This one, previously computed before the empirical estimation of the model, is not based on any strong economic parameter (Elhorst 2014). In order to compensate for such a lack, many papers check for the robustness of the empirical findings with respect to the spatial weights matrix used.

It should, finally, be highlighted that further development in the field of "network effects" are focused on "key players" (Ballester *et al*. 2006) and the endogenous formation of networks (Del Bello *et al*. 2014). The inclusion of these components in any analysis of technological change and induced spillovers effects would be promising. Firstly, key players, whoever they are, are assumed to play a prominent role. Agrawal and Cockburn (2003) provide *e.g.* some evidence regarding the positive impact of large, local, R&D-intensive firms - anchor tenants - on the regional innovation system in which they are located. Such anchor tenants enhance co-location of R&D activities and stimulate local knowledge spillovers. Focusing on scientists, Agrawal *et al*. (2014b) show that the hiring of a star scientist subsequently improves mainly the average quality of subsequent recruits regardless of whether they are involved in related or unrelated fields with respect to the star scientist. The impact on co-located incumbents appears positive only for those involved in the related fields. Urban economics, by focusing on multiplier effects, (see 5.3.d below), also pays greater attention to some players, *e.g.* high-tech or biotech industries (Moretti and Wilson 2014) or firms with high human capital jobs (Moretti and Thulin 2013). The endogenous formation of these phenomena supporting growth requires further attention.

5.3.d. Local multiplier effects

Urban economics focuses on local multiplier effects induced by an (exogenous) shock leading to the endogenous reallocation of factors and prices. Part of this indirect effect of the shock may be offset or enhanced by general equilibrium effects, while agglomeration economies may also play a role in the overall impact. The focus on specific industries as a source of shock also provides industry multipliers. Different settings have been considered in formal models and empirical applications. Those differ according to (1) the source of shock, (2) the target of the shock, (3) the types of firms or sectors indirectly impacted by the shock and (4) the inclusion of general equilibrium effects.

Three main sources of shocks are usually considered, *i.e.* labour supply, demand supply (Moretti 2011) and productivity (Hornbeck and Moretti 2015). In addition, the shock may find its source in a specific local event (Carrington 1996, Black *et al*. 2005, Weinstein 2014) or in a policy decision, including both place-based policies (Kline and Moretti 2014, Moretti and Wilson 2014) and public sector employment reallocation (Faggio and Overman 2014, Senftleben-König 2014).

As regards the target of the shock, the literature stresses that the impact of a shock differs according to the types of target which suffer the shock. Empirical applications are focused on either the tradable sector (Moretti 2010, 2011), some high-tech or biotech industries (Moretti and Wilson 2014) or firms with high human capital jobs (Moretti and Thulin 2013). The direct effects on non-traded sectors are usually not addressed.

For the indirect effect, empirical applications are less exclusive. Basically, trade and non-trade sectors are the focus of empirical exams (Moretti 2010 and 2011, van Dijk 2014). However, the origin of the shock is assumed to come also from the tradable sector. According to Moretti (2011), the size of the multiplier effect from the tradable sectors on the non-tradable sectors depends on three factors. The first one is consumers' preference for local goods/services and their respective elasticity of substitution between labour and capital. The second one is the kinds of new jobs initially created, as skilled workers earning higher wages may induce higher multiplier effects through a higher demand or a differential complementarity[9] (see *e.g.* Moretti and Wilson 2014, or Moretti and Thulin 2013, for empirical results). The third one is the elasticity of labour and housing supply. When these are not infinite, local shock increase local wages and land prices, partially offsetting the positive demand effect.

Moretti (2011) points out as well that the magnitude of the effect from the non-tradable sector to the tradable sectors depends on three factors. The first one is the higher local wages, set at national level, decreasing their competitiveness. To face

[9] See 5.4 for more details regarding differential complementarity.

such an issue, some firms are likely to relocate their activity to other local areas. The second one is the potentially higher demand addressed to firms producing intermediary goods. However, a large portion of suppliers are likely to be located somewhere else including in lower-cost countries. Therefore, a substantial impact is expected first of all for clustered industries. The third one is the fostering of agglomeration effects, if any, strengthening the overall impact.

Finally, while formal models detail the spatial equilibrium effects, empirical estimates do not necessarily focus on their specific impact as this requires additional local data regarding house prices and wages (spatial equilibrium effects will be examined in more detailed hereafter). The specific examination of general equilibrium effects, which is dedicated to highlighting those taking advantage of the shock, *i.e.* workers, landowners and firms, could provide an important contribution using our case study framework. Indeed, the relative strength of the price adjustments may be quite specific and in line with the peculiar characteristics of our case study, *i.e.* a small open economy. As the national market is rather small, any local shock is expected to have huge indirect effects on the others. However, external sources of labour supply through migration and daily commuting across the border may reduce such an impact, while commuting distances and own preferences for potential cross-borders may constrain such reduction. It should also be pointed out that access to at least local prices of housing and wages is required to carry out such an analysis.

In addition to these settings, short/long term effects may be examined using annual versus census data. For Blanchard and Katz (1992) it takes from five to ten years for regional adjustments to have effect. This length depends critically on the type of shocks and on local features. These adjustments take place through the so-called general equilibrium effects including labour and firm mobility, as well as house price adjustments. Cross-country analyses of specific local shocks have also been carried out (Moretti and Thulin 2013), introducing the additional effect of institutional and regulatory factors into the analysis.

Basic models focused on the multiplier effects of jobs across cities, for firstly the tradable and secondly the non-tradable sector, may *e.g.* take the following form (see Moretti 2010).

$\Delta N_{ct}^{NT} = \alpha + \beta \Delta N_{ct}^{T} + \gamma d_t + \varepsilon_{ct}$ (I.7.1)

$\Delta N_{ct}^{T1} = \alpha' + \beta' \Delta N_{ct}^{T2} + \gamma' d_t + \varepsilon'_{ct}$ (I.7.2)

With:

ΔN_{ct}^{NT} *as the change over time in the log number of jobs in city c in the non-tradable sector,*

ΔN_{ct}^{T} *as the change over time in the log number of jobs in city c in the tradable sector,*

ΔN_{ct}^{T1} *as the change in the log number of jobs in a randomly selected part of the tradable sector,*

N_{ct}^{T2} *as the change in the log number of jobs in the rest of the tradable sector,*

d_t *as a fixed time effect,*

ε_{ct} *as the unobserved random component*

It has to be noticed that, in empirical applications of this model, one may apply a shift-share instrument strategy (Bartik 1991) aimed at isolating exogenous shifts in the demand for labour in the tradable sector[10].

5.4 Spatial equilibrium models

The general spatial equilibrium assumption developed in urban economics is based on the hypotheses of the mobility of workers and firms and the limited elasticity of housing supply. Some basic models take from granted the full elasticity of labour supply and the full inelasticity of housing supply (*e.g.* Roback 1982), while more recent and realistic models assume that labour supply is not infinitely elastic and housing supply is not zero (Hornbeck and Moretti 2015). In the first setting, any shock to the local economy is capitalized in land prices and local welfare is unaffected. In the second setting, the impact of local shocks on workers' welfare is induced by the size of the local elasticity of labour and housing supply. Some additional models further consider search frictions hampering the immediate relocation of workers across local markets (Beaudry *et al*. 2014). Those models can provide an extension of basic multiplier effects (see Baum-Snow and Ferreira 2015).

Additional equilibrium conditions across space, based on workers' characteristics, have also been considered in urban economics. A first one is based on skill distribution across city size. Equilibrium skill distribution across cities is

[10] Moretti (2010) do so by using as instruments the weighted average of nationwide employment growth by industry.

assumed to be induced by differential skill complementarity. Such complementarity takes place in local externalities and, providing benefits to firms, affect the distribution of workers according to skills (sorting of workers by skills) at city level. Such complementarities also derive from the skill-biased literature. Indeed, Beaudry *et al*. (2010) assume that high-skilled local human capital provides a comparative advantage for the adoption of skill-biased technologies. The speed and extent of technology adoption is thus endogenous. Once such skill-biased technologies are adopted, they are supposed, in a second step, to either affect labour opportunities of other types of workers, or to increase demand for (service) workers with other kinds of skills. This leads to an at least indirect skills complementarity between high-skilled local human capital and other kinds of workers. It should, however, be observed that high-skilled workers may also be increasingly attracted to expensive cities by potentially confounding factors such as local amenities (Moretti *et al*. 2013).

The differential skills complementarity assumes the specific overrepresentation of some actors through micro-based mechanisms (cf. 3.). Two theoretical hypotheses in line with two kinds of empirical findings are proposed. The first one is extreme skill complementarity, with low-skilled workers providing in-person services and enhancing the productivity of high-skilled workers. This hypothesis derives from the thick tails found in large cities, high and low-skilled workers being overrepresented in large cities, while averagely-skilled workers are uniformly distributed by city size. (Eeckhout *et al*. 2014, Accetturo *et al*. 2014). The second assumption is top-skill complementarity, with high-skilled workers (top assistants) enhancing the productivity of superstars (see Behrens *et al*. 2014). This one finds its empirical basis in the first-order stochastic dominance of talent distribution by city size (Behrens *et al*. 2014, Bacolod *et al*. 2009). In both these cases, average workers are not assumed to differ across city size, differing, therefore, according to the sorting hypothesis (see 4). Moreover, the overrepresentation of some workers enhancing skill inequality in large cities suggests additional adjustment mechanisms, thus providing an alternative skill premium hypothesis. Indeed, as those living in a large city have to face higher costs of living, higher wages of average workers may compensate for these higher costs through general equilibrium effects.

An additional equilibrium condition across space, based on a specific degree of specialization of workers in routine tasks across local labour markets has been recently suggested by Autor and Dorn (2013a). In addition to the hypothesis derived from the polarization literature, that technological progress has a specific impact on labour market specialism in routine tasks, they assume that suppliers and customers of in-person services have to collocate. The latter is based on the assumption that low-skill services are non-storable and non-tradable. These two hypotheses lead them to the four following implications: markets historically specialized in routine-intensive industries should (1) displace workers from routine-task jobs, (2) follow employment polarization as low-skilled workers relocating in-person services, (3) experience larger wage growth at both ends of the skills distribution, (4) know larger net inflows of workers at both ends of the skills distribution.

6. Contribution and road map of the thesis

This thesis aims to clarify the relationship between innovation, location and employment growth. While innovation studies are focused on the identification of the effect of innovation on, amongst other things, employment growth, urban studies put to the fore the sorting of agents or the agglomeration phenomena taking place across space. Moreover, insofar as our contribution is above all empirical, data availability has to be taken into account in the setting-up of the thesis framework. Basically, our unit of analysis will consist of the firm, as innovation data is only available at this level of analysis. However, as every analysis of innovation and employment growth could suffer from a sample selection bias, due to firms' coverage, an additional unit of analysis will be used, *i.e.* the local area, for which employment data is fully available. All this leads us to split the dissertation into the following three main parts.

A first one is dedicated to examining the link between innovation, activity and firms' location. Basically, as innovation is assumed to belong to a firm's critical choice, a specific analysis of firms' involvement in innovation activity has to be done. Moreover, as a firm's large-scale sorting is expected to stand out at the local level, a firm's location has to be included in any analysis of innovation activity in order to not induce any bias in the coefficient of some explanatory variables[11]. The literature review will combine

[11] Firm's location may be correlated with both the random disturbance and some specific explanatory variables.

contribution from innovation studies and urban economics. Our aims and contributions will be detailed thereafter.

A second part focuses on employment growth by area regardless of innovation activity. Indeed, even if micro-data is available for examining innovation, employment and location all together, the data offering such opportunities suffers from sample restrictions induced by survey design. A first sample restriction relates to the exclusion of small firms, a second one to the exclusion of a large part of service activities, including personal services assumed to drive employment and wage polarization. Conversely, administrative data covering all individuals is available, offering a complementary examination of the link between employment growth and location. Moreover, such an examination will cover a bit more than a decade (1994-2005).

A third part combines the main three elements, *i.e.* innovation, location and employment growth. Even if such a part might suffer from potential sample selections, it will take advantage of firm-level data to provide further details regarding the demand side of the job market. In such an analysis, a firm's large-scale sorting is also assumed, putting to the fore the firm's varying behaviour across local areas.

As regards the empirical set-up of the thesis, three mains points have to be emphasized. A first one deals with the types of data in hand and therefore the unit of analysis that will be used and the kinds of mechanisms on which the analyses will be focused. A second one is about the types of location variables that will be used, and how agglomeration externalities will be addressed. A third one is about the inclusion of biased technological change in the thesis.

As regards the data available, two types of data will be used. The main one consists of the waves from the CIS survey carried out in Luxembourg and will focus on firms' behaviour with respect to their innovation activities. The second source is administrative data on employment at the individual level provided by the social security agency of Luxembourg (IGSS). These employee-level data will be aggregated at the level of spatial areas, becoming the second unit level of analysis in the thesis. Chapter 3 will be based on it. Using firm-level data as the main unit of analysis, the different chapters will not focus strongly on adjustments mechanisms at the aggregate level (5.3) or general equilibrium effects (5.4). Furthermore, the comparison between results deriving from chapters 4 and 5 as well as an extension to chapter 3, both carried out in chapter 6, will provide some insight regarding adjustment mechanisms at aggregate level.

As regards spatial adjustments, three types of spatial delimitations will be used: local labour markets or functional regions, accessibility to the mean centre, the trade-off between pooling advantages and poaching costs (see 3.2). The first one consists of local labour markets or functional regions, which are assumed to provide varying contributions to economic agents through sharing and matching learning. Their delimitations are based on commuters' behaviour. Five local labour markets will be considered, three belonging to the central area around Luxembourg City, and two to the peripheral areas. The second one is accessibility to the mean centre corresponding to the distance of each of the surveyed firms to the centre of gravity located in the north of the city of Luxembourg. Assuming a monocentric vision of the nation state, the accessibility to the mean centre provides a way of fine-tuning the analysis done according to functional regions or local labour markets. The third one is pooling advantage vs poaching cost. According to Combes and Duranton (2006a) a firm's location choice results from the trade-off between pooling advantages and poaching costs. They assume that knowledge is partly embodied in workers and that workers accumulate human capital on the job. As such, a dynamic wage premium is assumed. Two ways may be used to set up this trade-off, one derived from the relative position between the local labour markets, another one from the accessibility to the mean centre. However, as we will assume that accessibility will be less important during a downturn, the specific event on which we will focus, the first option will be retained by considering whether a given firm belongs to the central area. While local labour markets or functional regions will be used in every paper, accessibility to the mean centre will be considered only in chapter 2 and pooling advantage vs poaching cost only in chapter 5. Moreover, externalities will be included in most of the papers through control for local specialization/diversity and competition. The only exception will be chapter 3, which uses sectoral employment by local area as the unit of analysis, decreasing as such the usefulness of such controls.

As regards the bias of technological change (5.2), no focus on either skills-biased technological change or polarization will be managed in the chapters. Basically, our

CIS data does not provide any information regarding a firm's employment variations according to skills. Only the existing stock of employees according to skill level is available in our survey. In addition, our administrative data does not provide any information regarding the formal qualification (kind of diploma) or the specific occupation of employees (ISCO classification). The only information available is the main economic activity of the firm employing them (nace classification). Nevertheless, based on it, additional examinations of some results deriving from chapter 3 and the comparison between chapter 3 and 4 may provide some insight regarding the bias induced by technological change. Chapter 6 will focus on this issue amongst others.

The first part entitled: "firm's location and innovation activity within a metropolitan region" includes only one chapter**,** chapter 2. Chapter 2 studies the link between a firm's involvement in innovation activity and their location. When talking of firms' involvement in innovation, a basic distinction is made between three types of firms: those involved in both product/process and organizational innovation, those only involved in product/process innovation, and those only involved in organizational innovation. As regards location, two different concepts are considered. A first one is about functional regions defined according to commuters' behaviour. A second one is the accessibility to the centre, which offers the opportunity to examine non-linear variations in innovation activity across space.

Based on firm-level data, the "profile effects" and "agglomeration effects" that sustain innovation activities are set up according to 'average' enterprise characteristics in a given place. Basically, a firm profile effect $[\hat{f}(\bar{X}_{loc})/\ \hat{f}(\bar{X})]$ relates a firm's expected innovation in a given place to a firm's expected innovation in other places. Agglomeration effects $[\hat{f}(\bar{X}_{loc}, loc)/\hat{f}(\bar{X}_{loc})]$ relate a firm's expected innovation in a given place, taking into account the specific impact of a firm's location, to the expected innovation activity in this location. In both cases, average firms' characteristics are used to compute these expectations and are as such the exogenous source of variation. The profile effect highlights to what extent a firm's characteristics favouring innovation are more focused in a specific location, while agglomeration effects stress the relative additional contribution of a given location to innovation

These profile and agglomeration effects are computed for three types of involvement in innovation (*i.e.* product/process innovation only, organizational innovation only, and the combination of these two types of innovation), according to, firstly a firm's functional region and secondly, to a firm's accessibility. It has to be observed that accessibility requires additional specifications to be estimated. Moreover, confidence intervals are provided for the estimated "profile effects" and "agglomeration effects", increasing the robustness of our contribution.

Our results provide evidence regarding the varying local impact of these two effects for the three types of involvement in innovation. The varying profile effect is in line with the large-scale sorting of firms. The varying agglomeration effect is in line with local externalities assumed in urban economics (sharing, matching and learning). Our results suggest, in addition, that a firm's characteristics sustaining innovation also strengthen agglomeration effects, as our profile and agglomeration effects appear correlated.

The second part entitled: "employment growth within a metropolitan area" is dedicated to a single chapter, chapter 3. This chapter focuses on employment growth over time according to local areas. One may assume some labour-saving effects in the central areas. However, are these labour-saving effects increasing monotonically with the size of the local area? And what is the respective contribution of the sector to any potential labour-saving effect?

In order to examine this issue, we apply the Marimon and Zilibotti (1998) model in our infra-regional case. This model allows estimating variations due to geographical, sectoral, and time effects, or the recombination of these effects (*e.g.* sectoral contribution to regional growth).

$$e_{i,n,t} = h_i + m_{i,n} + b_t + f_{i,t} + g_{n,t} + \varepsilon_{i,n,t} \quad (1) \qquad i=1,\dots,I; \quad n=1,\dots,N; \quad t=1,\dots,T,$$

where $e_{i,n,t}$ is the growth rate of total employment in industry i in spatial unit n at time t;
h_i is a time invariant sectoral trend component that is shared by all spatial units;
$m_{i,n}$ is a time invariant effect that is specific to industry i and spatial unit n;
b_t is a pure time effect; $f_{i,t}$ is the interaction between a fixed industry and a time effect;
$g_{n,t}$ is the interaction between a fixed spatial unit effect and a time effect;
$\varepsilon_{i,n,t}$ is an idiosyncratic disturbance that is orthogonal to all other effects.

In order to identify the model, and in accordance with Marimon and Zilibotti, we impose various restrictions on the coefficients, in order to set them as orthogonal:

$\sum_{n=1}^{N} m_{i,n} = 0, I = 1,\ldots,I \ (R_1)$

$\sum_{i=1}^{I} f_{i,t} = 0, t = 1,\ldots,T \ (R_2)$

$\sum_{t=1}^{T} f_{i,t} = 0, i = 1,\ldots,I \ (R_3)$

$\sum_{t=1}^{T} g_{n,t} = 0, n = 1,\ldots,N \ (R_4)$

$\sum_{n=1}^{N} g_{n,t} = 0, n = 1,\ldots,T \ (R_5)$

$\sum_{t=1}^{T} b_t = 0 \ (R_6)$

To obtain a more direct and complete representation of regional effects on employment growth, five virtual economies are estimated. Each one estimates the rate of employment that each geographical unit would have reached if there had not been any regional effect [$m_{i,n} = g_{n,t} = 0$]. The virtual employment level is obtained by selecting the initial employment level (1994) of one economic sector and one geographical unit, and by applying the following sequence, with (h_i) as the sectoral growth, ($b_{t,}$) as the global growth, and ($f_{i,t}$) as the sectoral growth in t: $Evirt_{i,t} = h_i + b_t + f_{i,t}$. *(2)*

The empirical estimates highlight the lower employment growth in Luxembourg City and the relatively higher growth in the two areas belonging to the central areas that still benefit from proximity to the centre and where agglomeration effects should be concentrated. Such findings suggest a connection between the employment prospects of these three areas through a suburbanization process, in line with labour-saving effects that would monotonically vary within the central area. One may assume that the Luxembourg urban area and the suburban one, belonging to the central area, benefit from the relocation of activities that are less sensitive to distance and transaction costs. In addition, one can observe a diversifying periphery, notably in the south, where traditional industrial activities are being replaced by service activities.

To pursue this analysis, the previous indicator was recalculated for each sector in a given geographical unit from 1994 to 2005. To do this, we first slightly modified the Marimon and Zilibotti model by considering:

$$e_{i,n,t} = h_i + m_{i,n} + b_t + g_{n,t} + z_n + \varepsilon_{i,n,t} \quad (3)$$

i=1,…,I; n=1,…,N; t=1,…,T, with z_n *as a pure geographical effect.*

Then, based on (3), we computed a new virtual employment index based on the three following components: regional growth (z_n), global growth (b_t,), and regional growth in t ($g_{n,t}$): $Evirt_{n,t} = z_n + b_t + g_{n,t}$. (4)

Our extension of Marimon and Zilibotti (1998) model highlights that every sector contributes to the suburbanization of the centre. It also stresses the strong growth of other business services sustaining employment growth in the suburban area, and how land, transport, and postal services sustain it in the commuter areas.

It has to be underlined that, bearing in mind the potential sample selection induced by the CIS survey (examined below), we have extended this chapter 3 in chapter 6 in order to focus on the contribution to employment growth from CIS and non-CIS employers.

The third part entitled: "involvement in innovation and employment growth within a metropolitan region" includes two additional chapters, chapter 4 and chapter 5. Chapter 4 is dedicated to examining the link between location, innovation and employment growth. In order to do so, it departs from the structural model of Harrison *et al*. (2014), taking advantage of the CIS survey, and focusing on innovation and employment growth. Such a model is augmented in order to extend the analysis to local labour markets where firms are operating. The augmentation includes local market dummies, control for additional local externalities through specialization/diversity and competition and additional controls for firms' characteristics likely to confound the effect of product or process innovation on employment growth. Harrison *et al*. (2014) have derived a decomposition of employment growth taking advantage of the parameters estimated by the structural model and descriptive statistics. In line with our extension of their structural model, we have also adjusted this decomposition resulting in the combination of the impact of both firms' sorting and labour-saving effects that may be induced by product innovation.

The results stress that the influence of local externalities shifts firms' employment growth in opposite directions in the central and the peripheral areas. In addition, a labour-saving effect is found for innovative firms producing new products and operating in the central area. A further investigation, controlling for the similar characteristics of firms across areas through inverse propensity score weighting, suggests that this effect might derive from a specific skill-biased change in the central area. A decomposition of employment growth by areas is also carried out, taking into account the characteristics of firms and employment growth determinants by areas. The results suggest that two specific growth regimes related to regions or the life cycles of products might be operating within the Luxembourg metropolitan area: one for the central area, related to innovative activities, and another for the peripheral area, linked to lower costs.

Chapter 5 departs from these insights to wonder whether these insights are still valid when firms have to face adverse events due to either the overall economic situation or its own success on the product market. Basically, employment adjustments of firms operating in the central areas vs peripheral areas are compared. Location may induce cycle adjustments according to firms' economic environment in line with the poaching hypothesis assumed for large firms by Moscarini and Postel-Vinay (2012): large (central) firms that attract employment create more jobs when employment is below trend, and conversely destroy more jobs when employment is above trend.

Moreover, focusing on the adjustments across local labour markets one may assume that labour pooling adjustments would prevail over the other micro-determinants of agglomeration effects *i.e.* sharing and matching. Focusing on this micro-determinant, one may hypothesize that a firm facing a negative demand shock during a downturn is less likely to retain its employees (lower stickiness), insofar as it could take advantage of both higher likelihood of matching and better quality of match when growth returns. In addition, the existence of better matching before any slowdown in the central area may presume reduced opportunities from the liquidation of other firms, *i.e.* reduced opportunities to hire employees with skills unavailable to the firm, while increasing opportunities may arise in more sparse areas.

In order to examine these hypotheses empirically, we further extend the analysis by taking into account a firm's employment adjustments according to the overall economic situation and a firm's success on the product market. A first distinction is made between times of growth (2004-2006) and downturns (2008-2010). A second distinction is made between a firm's facing positive or negative net sales on the product market. In both situations, firms are assumed to have to adjust their human resources. This leads to examining firms according to four situations and therefore to split the structurally extended model into four sub-cases. In addition, a reweighting approach is introduced so as to control for non-random shock over local labour markets that firms have to face during a downturn and the multicollinearity between firm-level characteristics and firm location (such multicollinearity was not present in chapter 4).

Our results are consistent with firstly, a specific impact of labour pooling during a downturn, assumed to foster a rather negative adjustment of the labour force, and secondly, the poaching hypothesis combined with a differential employment trend between the central and peripheral areas. According to the latter, employment arising from poaching would be decreased in times of downturn.

Second part:
Firm's location and innovation activity within a metropolitan region

Chapter 2 : L'adoption d'innovations technologiques et/ou organisationnelles dans la région métropolitaine de Luxembourg[12]

[12] Cette recherche peut-être consultée via l'article: Dautel V. (2016). "L'adoption d'innovations technologiques et/ou organisationnelles dans la région métropolitaine de Luxembourg", *Economie et Prévision*, vol. 206-207 : 71–90

Third part:
Employment growth within a metropolitan area

Chapter 3 : Intra-regional employment growth in Luxembourg (1994-2005)[13]

[13] This research can be accessed via the following paper: Walther O. and Dautel V. (2010). "Intra-regional employment growth in Luxembourg (1994-2005)", *Geografiska Annaler: Series B, Human Geography*, vol. 92(1): 45–63

Fourth part:
Involvement in innovation and employment growth within a metropolitan region

Chapter 4 : Location, firm-level innovation and employment growth: an analysis within a metropolitan region

1. Introduction

Literature concerning innovation usually overlooks the role of location with regard to employment growth. However, at least three arguments support the suggestion of paying greater attention to external local factors. First, cluster literature highlights the importance of the local infrastructure for fostering innovation, especially with regard to new knowledge, which tends to be informal and uncodified (Pavitt 1987) and in the early phases of an industry's life cycle, when the returns from innovation are the highest (Klepper 1996). Second, it is assumed that proximity plays a major role with regard to exploiting knowledge spillovers, which are indeed spatially mediated (Audretsch and Feldman 1996). Some studies even suggest that knowledge spillovers tend to be geographically limited to the region where new economic knowledge was created (*e.g.* Anselin *et al.* 1997). Third, the distribution of skilled workers and firms or entrepreneurial capabilities varies over space, as well as across market opportunities and by local input. Skilled workers may be attracted to urban areas because of a static or dynamic wage premium (Rosenthal *et al.* 2004). In addition, firms or entrepreneurs may adjust their location according to the trade-off between local advantages – including access to larger markets (Baldwin and Okubo 2006) – and local disadvantages – including the cost of business premises.

Firms, however, have for a long time been neglected in literature dealing with the effects of geographical and regional economics on employment growth (Beugelsdjik 2007, Audretsch and Dohse 2007). Although literature about geographical and regional economics traditionally includes analyses dealing with the regional or local benefits of proximity or agglomeration (Glaeser *et al.* 1992, Boschma 2005), recent research shows that firms take specific advantages from their location, according to their own characteristics (McCann and Folta 2011, Knoben *et al.* 2015). Distinguishing between a firm's characteristics and its local environment is also expected to avoid over-estimating local opportunities and under-valuing the reaction of different firms to these opportunities. In line with this reasoning, Capello and Lenzi (2013) point out, using regional data, that firm-level analyses provide a more detailed and precise measurement of the direct link between technical change and employment.

The few papers dealing both with firm-level observations and location characteristics, essentially examine the effects of location or the impact of local factors on the success of innovation (Mariani 2004). Very few studies turn their attention to employment growth. As a result, Firm-level evidence concerning the effect of technical change on regional growth is limited. Among the available studies, Hoogstra *et al.* (2004), Audretsch *et al.* (2007) and Raspe *et al.* (2008) show that firm-level employment growth is related both to the urban context and to the characteristics of a company. They also find that being located in areas rich in knowledge or providing greater diversity fosters employment growth. However, these results are not uncontested. For example, North and Smallbonet (1996) emphasise that small and medium-sized rural enterprises generate significantly more jobs than those in urban areas, whereas non-urban areas are assumed not to favour access to cognitive skills. In addition, to the best of our knowledge, the effect within a local context of the introduction of in-house innovation – distinguished from innovations introduced in the neighbourhood – remains to be examined.

In the current paper, the process from innovation to employment growth, including local factors in the analysis, will be examined using firm-level data to reflect firm-specific factors. In order to deal with both aspects, a structural model is adapted from Harrison *et al.* (2014), with three main changes. The first is basically to add to the specification three local factors that are likely to mediate employment growth: specific area, specialisation and competition. In addition, an augmented model is developed with the aim of controlling for potential confounding factors, which are not randomly distributed over space and may be correlated with random disturbance. Moreover, we use inverse propensity score weighting (IPW), allowing us to estimate separately a local model for employment growth while controlling for the similarity of firms' characteristics across areas.

More specifically, in this study we focus on three types of factors that are not normally examined in cross-country analyses. The first is the specific effect of local externalities not deriving directly from innovation and induced by local advantages and disadvantages. The second is the specific effect of innovative firm activities across areas, which is likely to induce a labour-saving effect in the central area. The third is the decomposition of employment growth by areas, taking into account a firm's involvement in innovation.

The following section deals with these factors through a theoretical framework, focusing first on spatial productivity differentials and second on firm-level changes. The third section presents the data and case study, and in the fourth, we detail the empirical model deriving from Harrison *et al.* (2014). The fifth section discusses the empirical results and the last section concludes.

2. Theoretical framework

2.1 Spatial productivity differentials

Many studies highlight that innovative activities and their external spillover effects are geographically localised (Audretsch and Feldman 1996, Anselin *et al.* 1997, Mariani 2004). This derives from the specific advantages offered by geographical concentration. Three main types of externalities have been considered as enhancing this concentration: the Marshall-Arrow-Romer or localisation externalities related to industry specialisation, the Jacobs or urbanisation externalities stressing the role of diversity, and the Porter externalities emphasising local competition. Empirical studies typically find a strong and statistically significant positive relationship between the density of economic activity and productivity (*e.g.* Ciccone and Hall 1996).

Glaeser *et al.* (1992) and Henderson *et al.* (1995) have sought to separate the effect of these externalities related to employment growth. De Groot *et al.* (2015) synthesised the available empirical evidence through a meta-analysis. They conclude that there is an overall positive effect of diversity and competition on growth. However, they also highlight the strong sectoral temporal and spatial heterogeneity of their results, pointing out among other things the stronger effect of diversity in high-tech sectors. This heterogeneity is clearly evident in the findings of Henderson *et al.* (1995), as their results suggest that different agglomeration externalities relate to the life cycle of products and/or industries. Duranton and Puga (2001) formalise this viewpoint in their ‘nursery cities’ model. They show that diversified cities can serve as nurseries for firms, by providing a fertile environment favouring the development of new products, before these firms relocate to more specialised cities with lower costs. Their model supports the Jacobs’ (1969) externality hypothesis for diversified cities and the Marshall-Arrow-Romer externalities for specialised cities.

Moreover, large urban areas are supposed to be a breeding place for knowledge-intensive activities, because they favour the spread of knowledge, through among other things, face-to-face contacts (Storper and Venables 2004). This knowledge availability leads to an attractiveness process (sorting effect) for firms operating in knowledge-intensive sectors (which are assumed to be highly productive), as potential spillovers are assumed to be a crucial factor for their business. In addition, Baldwin and Okubo (2006) demonstrate that the most productive firms are more likely to move to large agglomerations offering large markets, while Melitz and Ottaviano (2008) show that larger markets attract more firms, which makes competition fiercer and causes less-productive firms to exit the market. The micro-determinants of agglomeration effects provided by Duranton and Puga (2004) also highlight the advantage of these areas in terms of favouring the sharing of knowledge, learning, and the match between economic actors.

Literature concerning the urban wage premium – showing that wages are higher in large urban areas (see Rosenthal *et al.* 2004 and Puga 2010 for a review) – supports the suggested spatial productivity hypothesis within metropolitan areas. The empirical evidence assumes that positive externalities operate in the urban environment, and not only inside firms.

2.2 Firm-level changes to employment across space, induced by innovation

As already highlighted, innovative firms and activities related to knowledge tend to be concentrated within specific areas. In addition to the varying likelihood of innovative activities over space, it can be assumed that there is a varying influence of firm-level innovative activities that will affect employment growth. However, the link between innovative activities and employment growth remains unclear. The first reason for this is that the effect of innovation on employment growth operates through different mechanisms, examined separately in relevant literature. The second is that few firm-level studies pay attention to the spatial productivity differentials previously highlighted.

With regard to the first point, innovation may not only affect employment growth directly, as the innovative activity of a firm may be complementary or subsidiary to other firms' products and processes. The main indirect effect of product innovation relates to the potential cannibalisation of older products from non-innovating competitors, inducing a labour-saving effect for the latter. The main indirect effect derived from process innovation relates to price variations, which are expected to decrease for the innovating firm, affecting non-innovating competitors in a competitive setting. Moreover, two externalities – knowledge spillovers and the complementarity with the products and/or components of other – are likely to positively support employment growth in other firms.

Taking advantage of microdata, we focus on the direct effect over space by considering compensation and/or displacement effects. Compensation effects relate to employment change with respect to demand, through costs decreasing as a result of process innovation, and increased demand fostered by product innovation. Compensation effects are accordingly assumed to support employment growth in both these cases. The positive effect of product innovation is, however, likely to be reduced by the substitution of a firm's old products with new ones through what is termed the 'cannibalisation' effect (Harrison *et al.* 2014). Displacement effects relate to the influence of innovation on a firm's demand, through the assumed labour-saving effects of process innovation, and less or different labour input for product innovation. Displacement effects include localised technical change (Atkinson and Stiglitz 1969) and skill-biased technical change, both assuming that technical change is not neutral. On the one hand, further development of localised technical change makes the distinction between general and contingent technological change (see Antonelli 2006a, 2006b). General technical change assumes more radical innovations supporting a significant technological bias, shifting the overall productivity level by increasing the outcome of every production factor including labour-force resources. Contingent technological change focuses on less-radical innovations. It assumes that such innovations only modify labour productivity, through the composition and weight of production factors, with the less productive being replaced by the more productive. It could be hypothesised, in line with Fitjar and Rodriguez-Pose (2011),[14] that radical innovations are infrequent in peripheral areas due to limited local opportunities.

On the other hand, skill-biased technical change (see Acemoglu and Autor 2011 for an overview of the relevant literature) assumes potential complementarity between innovative activity and highly-skilled workers. Innovation is accordingly assumed to strengthen their recruitment and even their wages. However, in order for a spatial differential to arise in that case, a lower pull/push effect from a non-urban area for highly-skilled workers has to be assumed. Different arguments from both sides of the labour market sustain such a shift. On the supply side, one could highlight the attraction of amenities for highly-skilled workers (Moretti 2004), attractive wage premiums (see above) and increasing opportunities for highly-skilled couples (Costa and Kahn 2000). On the demand side of the labour market, one could stress the specialisation of firms across space with regard to products in different life cycle stages.

Three kinds of factors may therefore arise in within-country analyses, which are not considered in cross-country analyses. The first concerns the specific effects of local externalities not deriving directly from innovation and induced by local advantages (local spillovers and micro-determinants of agglomeration effects) and local disadvantages (higher local costs, congestion effects, etc.), both fostering higher efficiency within the central area. A labour-saving effect is therefore assumed in this area (*i.e.* less labour input for a given level of production) resulting partially from general equilibrium effects. The second is the specific effect of a firm's innovative activities. Although an overall positive effect from product innovation is expected on employment growth, a negative or insignificant effect is expected from process innovation. These assumptions derive from literature dealing with technical change and firm-level employment growth, not taking into account any potential spatial effect (see Pianta 2005 for a literature review). With regard to spatial locations, a potential additional marginal effect of product innovation through a labour-saving effect fostering

[14] It has to be noted that Fitjar and Rodriguez-Pose focus their analysis on differentials across large urban regions and not within a metropolitan region as we do.

productivity growth may arise, whether this is measured as elasticity.[15] This expectation derives from our two hypotheses introduced above, *i.e.* (1) a specific localised technical change in the central area, (2) a specific skill-biased technical change in the central area supported by a lower elasticity of highly-skilled supply of labour to the peripheral area. The third factor, excluded from cross-country analyses, is a decomposition of employment growth by areas, taking into account both firms characteristics – including the likelihood of innovation – and the employment growth determinants by areas – including the fostering effects of firm-level innovative activities.

3. Data and case study

3.1 Spatial variables

Functional regions are used, in order to examine the innovation-employment growth process over space. The regions are defined according to Cheshire and Gordon (1998) as a set of local spatial units between which there is intense labour-market commuting. The resulting five intra-regional units, previously used in chapter 2 and in Dautel and Walter (2014), are based on an aggregation of municipalities (Local Administrative Unit Level 2, according to the EU Nomenclature of Territorial Units for Statistics). These five spatial units, which reflect centre-periphery dynamics on the basis of a monocentric vision of the nation state, are the following: 1) Luxembourg City; (2) The Luxembourg urban area, excluding Luxembourg City; (3) The suburban area, comprising municipalities in which the proportion of commuters working in the agglomeration was higher than 40 per cent of the active population in 2002; (4) The southern area, comprising municipalities in which the proportion of commuters working in the agglomeration was lower than 40 per cent of the active population in 2002 (and located in the country's southern former industrial basin); and (5) a commuter area, in which the proportion of commuters working in the agglomeration was also lower than 40 per cent of the active population in 2002. In the following sections, a complementary distinction between the central area and the peripheral area is retained, with the latter comprising the southern and commuter areas.

[15] According to the dataset that we use (CIS survey), only effect of one form of innovation, *i.e.* product innovation, can be measured as an elasticity.

In order to complete the set of local spatial attributes, attention is turned to two indices, which are useful for outlining Marshall-Arrow-Romer's, Porter's and Jacob's externalities: specialisation and competition. The specialisation index is measured by the location quotient for the functional region and industry in which the responding firm is active (based on its 2-digit NACE code). The competition index relates to the inverse of firm size in a particular functional region and industry (NACE 2-digits) and to the inverse of firm size in the national economy in that sector. On average, the rate of specialisation appears lower, and therefore diversity higher, in Luxembourg City than elsewhere (Annex 5-A1). Specialisation tends to be at its highest level in the peripheral regions. In addition, the competition indices are higher on average in Luxembourg City than elsewhere.

3.2 The community innovation survey (CIS)

The microdata used for examining both innovative activity and employment growth is taken from the EUROSTAT's Community Innovation Survey, carried out in Luxembourg by CEPS/INSTEAD on behalf of and under the methodological responsibility of the National Statistical Institute (STATEC). This survey provides firm-level data on the sales of new and old products, process and organisational innovation undertaken, the number of employees at the beginning and end of the three-year reference periods, and additional business characteristics. As firm-level data on growth is sensitive to business cycles, two recent waves (before the economic crisis) of this survey are pooled to reduce this potential weakness: CIS 2004–2006 and CIS 2006–2008.

The target population of this survey includes firms with at least 10 employees operating in the following activities: manufacturing industry, gas and electricity, wholesale and commission trade, transport and communications, financial intermediation, computer activities, R&D – engineering and consultancy – technical testing and analysis. The final sample covers close to 40 per cent of the target population and the sample size leads to precise estimations: for example, the coefficient of variation reflecting the sampling errors for the percentage of innovative firms is below 5 per cent. A high response rate (around 90%) provides, in addition, an adequate balancing of the sample by functional regions as highlighted in Table 4.1. No one region appears significantly under or over-represented in the two samples (Annex 5-A2).

3.3 Stylised facts for the Luxembourg functional regions

Firms operating in Luxembourg City, the urban area or the suburban area are substantially more likely to innovate, regardless of the type of innovation (Table 4.1). They are twice as likely to innovate in terms of products or processes compared with firms operating in the southern and commuter areas. However, the discrepancy is weaker in relation to organisational innovation, with this being almost as frequent in the southern region (44%) as in the central areas (from 49% to 55%). According to these results, innovative activities are therefore assumed to play a greater role – if any – in employment growth in the central areas than in the peripheral areas. The results are also in accordance with an involvement in earlier stages of life cycles for firms in the central areas, and later stages for those in the peripheral areas.

Table 4-1: Propensity to innovate across functional regions

	Luxembourg City (%)	Luxembourg urban area (%)	Suburban area (%)	Southern area (%)	Commuter area (%)
Product innovation	46	40	43	24	18
Process innovation	38	35	33	16	18
Organisational innovation	53	49	54	44	21
No. of observations	293	128	236	131	170

Notes: Figures are weighted.
Source: CIS (2004–2006) and CIS (2006–2008).

In order to complete the picture of the functional regions, the following characteristics of firms operating in the regions are examined: economic activity, employees' level of education, and size (Table 4.2). Firms in the southern and commuter areas mainly operate in low knowledge-intensive service sectors or medium to low-tech industries. By comparison, firms in Luxembourg City mainly operate in knowledge-intensive sectors, such as financial intermediation, computer activities and R&D – engineering and consultancy – technical testing and analysis. The focus on knowledge-intensive sectors can still be observed in firms in the urban and suburban areas. The study of company size highlights, in addition, that firms in Luxembourg City are no smaller than those in other areas, reflecting the fact that most of them are not in the embryonic stages of their industry life cycle. The level of education of employees confirms the discrepancy between Luxembourg City and to a lesser extent, the urban and suburban areas and the southern or commuter areas, suggesting that businesses in the latter two regions are engaged in more mature industries. Moreover, regardless of the location of firms, the proportion of higher-educated employees is found to be higher for innovating firms (43.9% in the central area and 33.5% in the peripheral area) than for non-innovating ones (31.4% and 12.4% respectively), in line with a potential skilled-biased fostering of innovation activity.

Table 4-2: Firms' characteristics across functional regions

	Luxembourg City (%)	Luxembourg urban area (%)	Suburban area (%)	Southern area (%)	Commuter area (%)
Economic activity					
High and medium high-tech industries	1.7	5.5	7.4	7.6	4.1
Medium low-tech industries	3.2	3.6	9.0	22.0	9.2
Low-tech industries	5.6	10.5	7.1	16.2	17.4
Gas and electricity	0.9	0.2	0.5	1.6	1.6
Wholesale and commission trade	11.5	21.2	24.3	21.1	28.9
Transport and communications	13.0	19.6	26.6	20.6	30.6
Financial intermediation	39.0	22.1	7.8	0.0	1.5
Computer activities	12.4	10.4	11.0	8.7	1.5
R&D – engineering and consultancy – technical testing and analysis	12.7	6.8	6.2	2.2	5.2
Size					
Small-sized firm (10-49 employees)	68.5	75.0	71.7	71.8	81.4
Medium-sized firm (50-249 employees)	24.6	18.4	21.9	20.7	15.6
Large-sized firm (>249 employees)	6.7	6.4	5.6	5.6	2.0
Additional characteristics					
Higher-educated employees (%)	43.4	37.0	30.5	23.1	16.6
Belonging to a group	55.2	51.2	43.5	37.7	29.3
Labour productivity	0.43	0.32	0.27	0.20	0.24
No. of observations	293	128	236	131	170

Notes: Figures are weighted. Source: CIS (2004–2006) and CIS (2006–2008).

A complementary descriptive analysis also highlights that additional basic characteristics likely to be related to employment growth are not randomly distributed across the areas. Indeed, firms in Luxembourg City, the Luxembourg urban area or the suburban area are clearly more likely to belong to a group and to have higher labour productivity.

4. The empirical model

Harrison *et al.* (2014) shed new light on the relationship between innovation and employment at the firm-level by disentangling some of the effects in operation. In addition to the distinction between product and process innovation, the relative contribution to new and old products is brought to the fore, as well as the displacement and compensation effects induced by product and process innovation. Product and process innovation are likely to induce net positive or negative growth due to the competing effects of displacement or compensation. This model (or slight variations of it) has already been applied in additional countries or empirical cross-country studies (*e.g.* Hall *et al.* 2008, Zuniga and Crespi 2013, Dachs and Peters 2014). An adaptation of the model, to account for the intra-regional context, offers the opportunity to examine in depth to what extent employment growth differs between the central and peripheral areas.

Harrison *et al.* (2014) decompose employment growth into the following four components: y_1 the rate of growth of old products, y_2 the rate of growth of new products, pc the introduction of process innovation and u an overall random disturbance.
$l = \alpha_0 + \alpha_1 pc + y_1 + \beta y_2 + u$ (IV.1)

It should be noted that the y_1 coefficient equals 1, highlighting three parameters of interest: α_0 representing the average efficiency growth in the production of an old product, α_1 the process innovation effect (in case pc = 1), and β the relative efficiency of the production of old and new products.

However, as highlighted by Harrison *et al.* (2014), two main issues have to be resolved for the estimation of this basic model. The first relates to the estimation of the relative efficiency of producing old and new products. To deal with this, growth in nominal sales needs to be substituted by growth in real production. As a firm's prices are not available, corresponding industry price indices π are used as a proxy.[16] In

[16] Industry price indices used are derived from the OECD STAN database for industrial analysis. Data was extracted in April 2013.

addition, $l - (g_1 - \pi)$ is used as the dependent variable, in order to identify the effect of process innovation on employment, net of (direct) compensating price variations. The second issue relates to an endogeneity problem due to the possible correlation of y_2 with productivity shock. To deal with this, appropriate instruments need to be found. In line with Harrison *et al.* (2014), the following two variables are used (measured on a 4-point scale): whether (1) the extension of the product range is considered as an important goal for the firm's innovation activity and whether (2) the clients are an important information source for innovative activity. Both are assumed to be correlated with sales of new products, while being uncorrelated with price or productivity shocks. We tested the strength and validity of our IVs by checking the F-statistic from the first stage regression, the Kleibergen-Paap tests on weak instruments and under-identification, and the Sargan-Hansen J-Test for over-identification.

The reference model becomes:

$$l - (g_1 - \tilde{\pi}_1) = \alpha_1 pc + \beta g_2 + v \qquad \text{(IV.2)}$$

With:

$g_1 = y_1 + \pi_1$	*: Sales growth due to old products*
$g_2 = y_2 + \pi_2 y_2$	*: Sales growth due to new products in the period*
π_1	*: Price growth rate of old products at the firm-level*
$\tilde{\pi}_1$	*: Price growth rate of old products at the industry level*
π_2	*: Price difference between a new and an old product in relation to the price of the old product*
$v = -E(\pi_1 - \tilde{\pi}_1) - \beta\pi_2 y_2 + u$	*: New random disturbance term*

In addition, Harrison *et al.* (2014) suggest an interesting way of taking advantage of the resulting estimates by decomposing employment growth into the following four components:

$$l = \underbrace{\textstyle\sum_j (\hat{\alpha}_0 + \hat{\alpha}_{0j}) ind_j}_{1} + \underbrace{\hat{\alpha}_1 pc}_{2} + \underbrace{[1 - I(g_2 > 0)](g_1 - \tilde{\pi}_1)}_{3} + \underbrace{I(g_2 > 0)\big(g_1 - \tilde{\pi}_1 + \hat{\beta} g_2\big)}_{4} + \hat{v} \quad \text{(IV.3)}$$

1. The first term reflects the change in employment related to general industry (α_{0j}) and overall productivity growth (α_0) in the production of old products (i.e. not innovative products).

2. The second term corresponds to the net employment contribution from process innovation in the production of old products.

3. The third term measures the employment change associated with the output growth of old products for firms not introducing any new products.

4. The fourth term synthesises the net contribution of product innovation to employment for product innovators, including the potential cannibalisation of old products by new ones.

The final term is the residual term (zero, on average).

Two main adaptions of this model are used in order to deal with local factors. The first one is to introduce on the one hand dummies corresponding to a firm's spatial location, and on the other hand, basic indices for specialisation and competition so as to control for local externalities. The second one is to augment the model by additional variables assumed to be correlated with both the local dummies and the random disturbance. These variables are: the proportion of highly-skilled employees, the firm's labour productivity, firm's size, and whether the firm belongs to a group. In addition to these two main changes, the potential effect of the period 2006–2008 compared with 2004–2006 – as well as organisational innovation, which is only available in recent surveys – are also controlled for. Changes in organisation are expected to be aimed at making a firm more efficient or reducing costs. They are therefore likely to affect a firm's employment rate. In line with Harrison *et al.* (2014), industry effects are also considered. The reference model used is therefore as follows:

$$l - (g_1 - \tilde{\pi}_1) = \alpha_1 pc + \beta g_2 + \alpha_2 org + \alpha_3\, i + \alpha_4 comp + \alpha_5 spe + X'\delta + v \qquad \text{(IV.4)}$$

org=organisational innovation; i=spatial unit; comp=competition indice; spe=specialisation indice; X=vector of additional firm characteristics.

In addition, employment growth is decomposed by functional regions within the central and peripheral areas.

5. Empirical results

5.1 Descriptive results

Descriptive results related to the empirical model are examined in order to gain an initial insight. Four main types of variables are provided for the five spatial units: employment growth, sales growth, productivity growth and price growth. All of these results are separated according to a firm's innovation status (Table 4.3).

Employment growth by innovation status is in accordance with Harrison *et al.* (2014): specifically, slower in non-innovating firms, the main exception being Luxembourg City. Among the innovating firms, those experiencing higher growth are involved in product (16.8%) and organisational innovation (16.0%). Moreover, sales growth follows the same overall pattern as employment growth. Sales growth is slightly slower for non-innovating firms and faster for product and organisational innovators. In addition, sales growth is more clearly greater in the central areas than in the peripheral areas. The examination of sales growth also suggests a cannibalisation of older products by new products in peripheral areas, with the sales growth of old products becoming negative.

In addition, employment growth does not appear to differ significantly by functional units. The current results suggest only a slightly weaker comparative growth in two areas, the suburban area (13.6%) out of the central areas, and the southern area (13.1%) out of the peripheral areas. These descriptive results are therefore not in accordance with those reported in chapter 2, based on a large sectoral coverage including less knowledge-intensive activities[17] more likely to expand in low-cost areas, with lower employment growth in Luxembourg City than elsewhere regardless of the period under review (from 1994–1996 to 2002–2005). The discordance may suggest a peculiar role of sectoral coverage in employment growth, and therefore suggest paying particular attention to its potential impact on the comparability of previous studies. Further studies of Audretsch *et al.* (2007) and Raspe *et al.* (2008), in comparison with North and Smallbonet (1996), similarly show that these diverging results are related to different sectoral bases: technology based or knowledge-intensive sectors for the two former studies, and large sectoral coverage for the latter. To go beyond these first insights, the firm-level econometric results are examined based on an adaptation of the model of Harrison *et al.* (2014).

[17] Additional sectors covered include construction, retail trade, hotels, and restaurants: markets that offer less knowledge-intensive services.

Table 4-3: Growth of employment and sales by functional regions (2004–2008).

	Luxembourg City	Luxembourg urban area	Suburban area	Southern area	Commuter area	Metropolitan area
Employment growth (%)						
All firms	15.8	17.1	13.6	13.1	15.3	*15.0*
Non-innovators	21.5	16.6	7.6	8.9	16.1	*14.7*
Process innovators	12.4	19.9	19.1	14.7	13.1	*15.5*
Organisational innovators	14.2	19.5	18.1	16.7	11.0	*16.0*
Product innovators	13.0	22.5	18.5	24.3	13.0	*16.8*
Sales growth (%)						
All firms	28.9	26.9	28.1	21.8	17.5	*25.4*
Non-innovators	30.6	27.3	19.9	17.5	15.9	*21.5*
Process innovators	26.9	24.2	27.2	20.4	19.2	*25.3*
Organisation innovators	33.3	27.4	36.0	28.8	23.9	*31.9*
Product innovators	28.0	27.7	36.4	24.2	26.8	*29.9*
Of which:						
Old products	*4.6*	*2.8*	*1.9*	*-11.2*	*-7.5*	*1.3*
New products	*23.4*	*25.0*	*34.5*	*35.4*	*34.3*	*28.7*
Productivity growth (%)						
All firms	13.1	9.8	14.6	8.6	2.2	*10.4*
Non-innovators	9.1	10.6	12.3	8.6	-0.2	*6.8*
Process innovators only	14.5	4.3	8.1	5.7	6.1	*9.7*
Organisational innovators only	19.1	7.9	17.9	12.2	13.0	*15.9*
Product innovators	15.1	5.2	17.9	-0.1	13.7	*13.2*
Price growth (%)						
All firms	6.1	7.4	6.6	7.2	6.6	*6.6*
Non-innovators	4.5	6.4	4.8	5.2	6.1	*5.3*
Process innovators	6.7	10.2	5.7	2.1	2.1	*5.4*
Organisational innovators	6.2	9.9	7.7	8.6	4.5	*7.3*
Product innovators	6.3	6.1	6.4	6.6	2.8	*6.0*
Observations	293	128	236	131	170	*958*

Notes: Firms with a turnover change of at least 10% as a result of mergers, closures or scissions as well as firms with employment or sales changes > 200% or < -50% are excluded.
All figures are weighted.
Source: CIS (2004–2006) and CIS (2006–2008).

5.2 Econometric results

The econometric analysis focuses on two factors within our metropolitan region that are likely to mediate employment growth. The first concerns the specific effects of local externalities, the second is about the specific effects of innovative activities by area. In order to accomplish this, an overall model covering both the central and the peripheral area is used for the first case, and separate models by areas are used for the second one.

As mentioned earlier, dummy variables corresponding to spatial location and indices for specialisation and competition are additionally introduced into the model of Harrison *et al.* (2014) in order to deal with local externalities. We basically assume that spatial dummies for the three central areas will exhibit an opposite sign with respect to the two peripheral areas. However, in order to save some space in the drafting of the tables, no specific results are provided for the three central areas that are used as the baseline. The additional results can be provided on request.

To begin the investigation, we focus on the full model covering both main areas. The results show (1.0, Table 4.4) no evidence of employment reduction through process innovation (displacement effect). The introduction of product innovation mainly induces compensation effects favouring employment growth. In addition, the elasticity of employment from new product sales using the study's instruments is less than 1, suggesting productivity gains from new products. This effect – which has not been found in cross-country studies – might derive from the focus of our study on a metropolitan region fostering firms' competitiveness. The potential cannibalisation of old products by new products does not alter the results. The inclusion of organisational innovation in the analysis is not neutral; the results suggest a displacement effect from this. Conversely, the period does not have any effect. The specific results therefore confirm the main initial insights (Harrison *et al.* 2014, Hall *et al.* 2008), namely a strong positive effect from new products and no clear evidence of a negative effect from process innovation, adding a potential negative effect of organisational innovation as well as strengthened productivity gains from new products that might be fostered by a metropolitan regional context.

The inclusion of the spatial units in the analysis appears promising (1.1). In comparison to the central area, a positive effect of the southern area and the commuter area on employment growth is found, although the former is only weakly significant (p-val= 0.11). These spatial unit effects are in line with the assumed urban wage premium related to productivity differentials across functional areas. Accordingly, they highlight the presence of negative local externalities in the central areas (respectively positive in the peripheral areas) affecting employment growth. The inclusion of additional controls for specialisation and competition (1.2) strengthens these results, with the southern area effect becoming clearly significant. It should, however, be noted that overall, the specialisation effect and competition effect do not appear significant per se. One may assume, in line with Combes and Gobillon (2015), a compensation effect between these two components. In accordance with this assumption, the specialisation effect becomes significant and still negative when the competition effects are excluded from the analysis (1.3). This result is in line with the findings of Hoogstra *et al.* (2004); that firms facing greater diversity in their area benefit from higher employment growth.

In order to check the robustness of these results, we further augment the model of Harrison *et al.* (2014) by controlling for additional firm characteristics likely to both vary by area and to be correlated with the random disturbance. These characteristics, which were excluded from the analysis and are likely to confound the results, are the following: firm's size, belonging to a group, labour productivity and the skills of employees. These control factors are normally used in firm-level empirical applications dealing with innovation output; they are therefore likely to indirectly foster a firm's growth. Furthermore, Dachs and Peters (2014) recently highlighted the effect of group membership in the innovation employment growth process. The results point out that size and skill effects are not significant (1.4), whereas group membership (in accordance with Dachs and Peters 2014) and firms' labour productivity appear clearly significant. It has, however, to be stressed that these two factors do not substantially modify the significance of spatial areas: for the southern and suburban areas, the direction of the relationship is as expected and significant.

Table 4-4: Econometric results

	All Areas					C. Areas	P. Areas
	(1.0)[1]	(1.1)	(1.2)	(1.3)	(1.4)	(2.0)	(3.0)
Sales growth d.t. new products (g_2)	0.76*** (0.13)	0.81*** (0.13)	0.82*** (0.13)	0.82*** (0.13)	0.88*** (0.14)	0.92*** (0.18)	0.90*** (0.24)
Process inn. only	0.17*** (0.05)	0.17*** (0.05)	0.17*** (0.05)	0.17*** (0.05)	0.16*** (0.04)	0.20*** (0.05)	0.09 (0.08)
Organ. inn. only	-0.12*** (0.04)	-0.11** (0.04)	-0.10** (0.04)	-0.10** (0.04)	-0.09** (0.04)	-0.08 (0.06)	-0.08 (0.07)
2006–2008	0.03 (0.03)	0.03 (0.03)	0.03 (0.03)	0.03 (0.03)	0.04 (0.03)	0.03 (0.04)	0.07 (0.05)
Joint significance of sect. dummies	$\chi^2(7)$= 16.72**	$\chi^2(7)$= 17.18**	$\chi^2(7)$= 15.61**	$\chi^2(7)$= 15.62**	$\chi^2(7)$= 10.37	$\chi^2(7)$= 11.56	$\chi^2(7)$= 16.18**
Central areas	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.	Ref.
Southern area		0.07 (0.04)	0.08** (0.04)	0.08** (0.04)	0.07* (0.04)		
Commuter area		0.08** (0.03)	0.08** (0.04)	0.08** (0.04)	0.07** (0.04)		
Specialisation			-0.03* (0.02)	-0.03* (0.02)	-0.02 (0.02)	-0.01 (0.02)	0.00 (0.07)
Competition			0.00 (0.00)		0.00 (0.00)	0.00 (0.00)	0.01 (0.01)
% of Skilled employees					-0.01 (0.08)	-0.03 (0.10)	0.07 (0.12)
Medium-sized firm					-0.00 (0.03)	0.02 (0.04)	-0.06 (0.04)
Large-sized firm					0.00 (0.05)	-0.01 (0.05)	-0.01 (0.08)
Belonging to a group					-0.12*** (0.03)	-0.13*** (0.04)	-0.11** (0.04)
Labour productivity					0.09*** -0.01	0.11*** -0.03	-0.04 0.07
Constant	-0.10* (0.06)	-0.12* (0.06)	-0.08 (0.07)	-0.08 (0.07)	-0.06 (0.06)	-0.10 (0.08)	0.16 (0.12)
Partial R^2	0.17	0.16	0.20	0.20	0.18	0.20	0.18
R^2	0.25	0.25	0.26	0.26	0.28	0.26	0.33
Observations	939	939	939	939	939	643	296

[1] Instruments are 'Increased range of goods or services' and 'Customers as information sources'.
Notes: Firms with a turnover change of at least 10% as a result of mergers, closures or scissions as well as firms with employment or sales changes >200% or < -50% are excluded. The 2% top labour productivity are also excluded.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
Estimates are based on pooled data. Estimates are weighted. Standard errors are clustered.
Partial R^2 report the explanatory power of the instruments used in the first regression stage.
Under-identification; Kleibergen-Paap rk LM statistic (p-val): 0.000 (1.0), 0.000 (2.0), 0.000 (3.0)
Weak identification; Kleibergen-Paap Wald rk F statistic: 59.55 (1.0), 44.92 (2.0), 12.64 (3.0)
Hansen J test on over-identifying restrictions (p-val): 0.937 (1.0), 0.806 (2.0), 0.507 (3.0)
Exogeneity test (OLS vs. IV) (p-val): 0.842 (1.0), 0.444 (2.0), 0.356 (3.0)
Source: CIS (2004–2006) and CIS (2006–2008).

To complete the investigation, firms from the central and peripheral areas are separated in order to examine two additional issues. The first is whether the overall effects of the different types of innovation fit these both specific cases. The second and most important aim is to deal with the potential spatial productivity differential that may arise directly from changed elasticity of employment resulting from the sale of new products (Table 4.4). In order to run these tests, the augmented model is used. With regard to the first issue, the results from the central area follow the overall results (2.0), as expected according to the area's size (2/3 of the sample). For the peripheral area (3.0), the effect of process innovation remains positive and the influence of organisational innovation negative, but neither is any longer significant. With regard to the second issue, the elasticity of employment from new product sales appears, for both areas, below or just below 1, in line with productivity gains from new products. However, and in contrast to what was expected, this gain is not higher in central areas (2.0), where higher productivity (growth) was expected, than in the peripheral areas (3.0). It should be stressed, however, that both elasticities arise from separate sub-models not controlled for the particular characteristics of firms operating in these areas and likely to affect such elasticities. Indeed, firms operating in these two areas differ, at least regarding their involvement in knowledge-intensive activities. Moreover, for the peripheral area sub-model, the size of the distortion deriving from the IV estimate is potentially large (from 15% to 20% according to the Stock-Yogo critical values).

In order to bypass this limitation, we follow the reweighting approach suggested by Nichols (2008), and Hirano *et al.* (2003). Accordingly, the propensity score of the likelihood of belonging to the peripheral area is computed and the sample is then restricted to common support. This done, the remaining observations from the two subsamples are matched by reweighting them according to the renewed propensity score,[18] before conducting the estimates again using the new weights (Table 4.5). The size of the distortion that may be induced by the IV estimate appears to be reduced for the peripheral area sub-model (to less than 10%). Moreover, the resulting elasticities from these adjusted samples are in line with the expectations (2.1 and 3.1), *i.e.* significantly lower in the central areas than in the peripheral areas (g2 = 0.72 vs g2 =

[18] The propensity score (_ps) was estimated by a logit model using the following observable variables: company size, belonging to a group, % of higher-educated employees, sectoral affiliation, and process and organisational innovation (see Annex 5-A4). This was used to reweight firms belonging to the central areas as: (_ps)/(1-_ps).

1.07; $\chi^2(1) = 7.70$; $p\text{-val} < 0.01$) reflecting an additional spatial productivity differential through product innovation. This shift is in line with our two hypotheses: (1) a specific localised technical change in the central area, and (2) a specific skill-biased change in the central area supported by a lower elasticity of highly-skilled supply towards the peripheral area. In the first case, more radical innovation in the central area may foster overall productivity growth. In the second case, innovation activity in the central areas may be followed and/or sustained by the hiring of highly-skilled workers.

The basic strategy that we follow to check these two hypotheses is to control as far as possible for the mechanisms supporting specific localised technical change, assuming that the remaining shift between areas might be related to varying skilled-biased change across areas that we do not control for. Indeed, while some variables relating to firms' involvement in R&D (fostering radical innovation) and the degree of novelty of their products can be used to control for assumed spatial differential related to specific localised technical change, none are available for the spatial shift related to skill-biased change. In practice, the available characteristics are controlled for in the propensity score matching, so that firms from both areas are similar – even according to these characteristics – before running the regressions. With regard to firms' involvement in R&D, two variables are used: whether firms are involved in R&D at all, and if so, the proportion of personnel involved in it. In addition, two variables are used to reflect the degree of novelty of a firm's products: whether firms have products new to their market, and if so, the share of these products in the firms' turnover.

Table 4-5: Additional Econometric results following inverse propensity score weighting

	C. Areas	P. Areas	C. Areas	P. Areas	C. Areas	P. Areas	C. Areas	P. Areas
l-(g_1-π)	(2.1) [1, 2]	(3.1) [1, 2]	(2.2)	(3.2)	(2.3)	(3.3)	(2.4)	(3.4)
Sales growth d.t new products (g_2)	0.72*** (0.13)	1.07*** (0.25)	0.71*** (0.12)	0.91*** (0.21)	0.74*** (0.12)	0.92*** (0.22)	0.87*** (0.18)	1.13*** (0.23)
Process inn. only	0.13** (0.05)	0.10 (0.08)	0.13** (0.05)	0.10 (0.08)	0.12** (0.05)	0.10 (0.08)	0.11 (0.09)	0.03 (0.09)
Organ. inn. only	-0.08** (0.04)	-0.07 (0.05)	-0.08** (0.04)	-0.07 (0.05)	-0.09** (0.04)	-0.08 (0.05)	-0.09 (0.06)	-0.03 (0.05)
2006–2008	-0.00 (0.03)	0.06 (0.04)	-0.01 (0.03)	0.06 (0.04)	0.01 (0.03)	0.06 (0.04)		
Joint significance of sect. dummies	$\chi^2(6)$= 21.34***	$\chi^2(6)$= 16.68**	$\chi^2(6)$= 23.30***	$\chi^2(6)$= 15.96**	$\chi^2(6)$= 17.00***	$\chi^2(6)$= 16.01**	$\chi^2(6)$= 17.28***	$\chi^2(6)$= 23.78***
Specialisation	-0.04** (0.02)	-0.02 (0.02)	-0.04** (0.02)	-0.02 (0.02)	-0.04* (0.02)	-0.02 (0.02)	-0.04 (0.03)	-0.03** (0.01)
Competition	-0.00 (0.00)	0.01 (0.03)	-0.00 (0.00)	0.02 (0.03)	-0.00 (0.00)	0.02 (0.03)	-0.00 (0.00)	-0.04 (0.03)
Additional firms' characteristics	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
Partial R^2	0.26	0.13	0.26	0.16	0.26	0.16	0.24	0.17
R^2	0.16	0.34	0.17	0.33	0.17	0.33	0.18	0.62
Observations	642	293	643	293	642	294	324	143

[1] Instruments are 'Increased range of goods or services' and 'Customers as information sources'.
[2] The restriction of the sample to common support leads to removing four firms.
Notes: Firms with a turnover change of at least 10% as a result of mergers, closures or scissions as well as firms with employment or sales changes >200% or < -50% are excluded. The 2% top labour productivity are also excluded.
* Significant at 10%; ** significant at 5%; *** significant at 1%.
Estimates are based on pooled data. Estimates are weighted. Standard errors are clustered.
Partial R^2 report the explanatory power of the instruments used in the first regression stage.
Under-identification; Kleibergen-Paap rk LM statistic (p-val): 0.000 (2.1), 0.000 (3.1)
Weak identification; Kleibergen-Paap Wald rk F statistic: 108.84 (2.1), 21.30 (3.1),
Hansen J test on over-identifying restrictions (p-val): 0.684 (2.1), 0.557 (3.1)
Exogeneity test (OLS vs. IV) (p-val): 0.17 (2.1), 0.277 (3.1)
Source: CIS (2004–2006) and CIS (2006–2008).

Controlling for similar involvement in R&D activity across the central and peripheral areas, the spatial differential between these areas decreases slightly for the elasticity of employment growth with respect to the new sales (see 2.2 and 3.2). The remaining shift (0.71 vs 0.91; $\chi^2(1) = 2.72$; p-val< 0.10) is still significant and in favour of higher labour productivity related to new products in the central area. The control for similar involvement across areas to products new to the market (see 2.3 and 3.3), before running the regressions, leads to the remaining shift across areas decreasing slightly more, and becoming no longer significant (0.74 vs 0.92; $\chi^2(1) = 1.89$; p-val= 0.17). Even if the remaining shift is not clearly significant in both cases, the main shift between areas is maintained, at least at an unusually low significance level, suggesting that something else – such as a stronger skill-biased change in the central area compared with the peripheral area – might be supporting the spatial differential. An alternative hypothesis for this spatial differential could be capital saving effects in the central area, complementing the product innovation of firms. However, no information is available in our dataset about capital stock to enable us to test this.

Before concluding the econometric analysis, we should highlight that specific differentials could arise at the end of the 2006–2008 period, fostered by the beginning of the economic crisis and potentially confounding our estimates. In order to check for this issue, and as a robustness test, we focused only on the 2004–2006 period. The results highlight a differential across areas according to the elasticities of employment growth with respect to new sales (2.4 and 3.4). This result is fully in line with the results for the full period 2004–2008 examined above (see 2.1 and 3.1), even if the shift is not statistically significant at the usual reference level due to the smaller samples used. Basically, a 0.2 differential between these two areas is still present (0.87 vs 1.13; $\chi^2(1) = 2.07$; p-val= 0.15).

5.3 The decomposition of employment growth by functional regions

The components of employment growth are examined by taking functional regions within the central and peripheral areas. The aim of these decompositions is to summarize, on the one hand, the average characteristics of a given location likely to influence employment growth, and on the other hand, the specific effects of local employment growth determinants. In practice, equations (5) combine the resulting estimates from the central areas (Table 4.6) with the corresponding average company characteristics of their respective functional regions (*i*), including the firms' overall involvement in innovation. Equation (4b) follows this set-up for the peripheral areas.

$$l_i^* = \sum_j (\hat{\alpha}_0 + \hat{\alpha}_{0j})\overline{ind}_{j,i} + \hat{\alpha}_1\overline{pc}_i + \hat{\alpha}_2\overline{org}_i + [1 - I(g_{2,i} > 0)](\bar{g}_{1,i} - \tilde{\pi}_{1i}) + I(g_{2,i} > 0)(\bar{g}_{1,i} - \tilde{\pi}_{1,i} + \hat{\beta}\bar{g}_{2,i}) + \hat{\alpha}_3 i + \hat{\alpha}_4\overline{comp}_i + \hat{\alpha}_5\overline{spe}_i \quad \textbf{(IV.5a)} \quad i=1 \text{ to } 3$$

$$l_i^* = \sum_j (\hat{\alpha}_0 + \hat{\alpha}_{0j})\overline{ind}_{j,i} + \hat{\alpha}_1\overline{pc}_i + \hat{\alpha}_2\overline{org}_i + [1 - I(g_{2,i} > 0)](\bar{g}_{1,i} - \tilde{\pi}_{1i}) + I(g_{2,i} > 0)(\bar{g}_{1,i} - \tilde{\pi}_{1,i} + \hat{\beta}\bar{g}_{2,i}) + \hat{\alpha}_3 i + \hat{\alpha}_4\overline{comp}_i + \hat{\alpha}_5\overline{spe}_i \quad \textbf{(IV.5b)} \quad i=4 \text{ to } 5$$

org=organisational innovation; comp=competition indice; spe=specialisation indice; i=spatial unit.

According to these two decompositions, the main contributions to employment growth differ between firms from the central and peripheral areas (Table 4.6). For the former, the net contribution from the introduction of new products (including the cannibalisation effect) supports nearly two thirds of employment growth, against one third in the peripheral areas. The specific cannibalisation of old products by new ones does not appear to play a substantial role in these changes.

In accordance with the econometric results, specialisation has a negative impact on employment growth in both areas. This effect is, however, weaker within Luxembourg City, where specialisation is lower (and diversity is relatively strong). Conversely, competition appears to only weakly affect employment growth in the peripheral areas. The overall local effects obtained by accumulating the spatial unit, competition and specialisation effects, are still more in favour of employment growth in central areas than in peripheral areas. It has to be stressed, however, that opposite overall effects are found when applying a single decomposition using only one model, not allowing therefore specific beta coefficients for the central and peripheral areas. In this case, local effects are clearly negative in Luxembourg City and the suburban area (-6.7 and -9.7) while being moderately positive in the commuter area (see 2.5) and in the southern area (-1.1).

Moreover, the contribution of process or organisational innovation is relatively similar across the different spatial units, while a higher impact from old products seems to be found in the central area. This result may suggest the potential complementarity of process or organisational innovation on the production of old products, with new processes or organisational methods being expected to support customer appeal for existing products.

Table 4-6: Central and peripheral areas: employment growth decomposition by functional regions (%)

	Luxembourg City	Luxembourg urban area	Suburban area	***Central area***	Southern area	Commuter area	***Periph. area***
Total empl. growth (%)*	15.6	17.4	13.8	***15.3***	12.7	15.1	***14.1***
Prod. trend in old prod.	-4.0	-3.6	-1.8	***-3.1***	7.3	8.8	***8.1***
Net contrib. of proc. inno.	1.5	1.4	1.9	***1.6***	0.5	1.0	***0.8***
Net contrib. of org. inno.	-2.2	-2.1	-2.1	***-2.2***	-3.2	-1.2	***-2.0***
Old products	12.2	10.3	8.7	***10.6***	10.0	6.8	***8.2***
Net contrib. of prod. inno.	9.4	8.6	11.6	***10.1***	3.2	3.3	***3.3***
Old products	*-1.2*	*-2.6*	*-2.7*	***-2.0***	*-4.4*	*-2.3*	***-3.2***
New products	*10.6*	*11.2*	*14.4*	***12.1***	*7.6*	*5.6*	***6.5***
Local effects	-1.2	2.8	-4.5	***-1.6***	-5.2	-3.6	***-4.3***
Spatial unit effect	*-0.2*	*5.0*	*-3.7*	***-0.5***	*-0.1*	*0.1*	***0.0***
Competition effect	*0.2*	*0.0*	*0.0*	***0.1***	*1.3*	*1.4*	***1.4***
Specialisation effect	*-1.1*	*-2.2*	*-0.8*	***-1.2***	*-6.4*	*-5.1*	***-5.7***

* Divergences with the descriptive results are due to rounding and use of a unique model for the three central areas and another one for the two peripheral areas.
Notes: Estimates are weighted.
Source: CIS (2004–2006) and CIS (2006–2008).

6. Conclusion

The aim of this article was to provide new evidence regarding the micro-mechanisms favouring employment growth within a metropolitan region. To do so, the model developed by Harrison *et al.* (2014) was adapted by linking firms' innovative behaviour to firm-level employment growth within a metropolitan region. The results highlight the influence of the specific locations where firms operate, through the opposing effects of local externalities depending on whether firms operate in the central or peripheral area. They also stress a labour-saving effect induced by firms' sales of new products in the central area. The complementary econometric analysis, controlling for similar firm characteristics across areas using inverse propensity score matching, suggests that the resulting labour-saving effect in the central areas may be related more to specific skill-biased change than to specific localised technical change. Moreover, the decomposition of employment growth by areas suggests that two specific growth regimes related to the life cycles of products or regions are operating within the Luxembourg metropolitan area: one for the central area related to innovative activities, and particularly new product development, and another for the peripheral area resulting from lower costs of business premises.

It should, however, be noted that the present research has some limitations. First, the firm-level effect of product innovation does not include any ‘business-stealing’ component, meaning that employment increases by product innovators may be, overall, at the expense of their non-innovating competitors. Second, it could be hypothesised that product market competition has some impact on the demography and mobility across areas of rival firms. Third, information regarding a firm’s outsourcing may also be relevant in any attempt to examine the impact of firm-level innovation on other firms from diverse locations. It can indeed be expected that a proportion of the innovative activities carried out in the central area supports subsequent employment growth in supplying firms from the peripheral area, which benefit from lower costs. Fourth, the present findings reflect a time of growth. One might hypothesise that the most productive firms and the ones located in areas rich in knowledge stand out in a time of economic downturn by either preserving their own skilled staff or by taking advantage of available skilled resources and lower opportunity costs.

Annex 4-A1: Average specialisation and competition index across functional regions

Index	Specialisation			Competition		
	Mean	Lower band 95% CI	Upper band 95% CI	Mean	Lower band 95% CI	Upper band 95% CI
Luxembourg City	1.17	1.10	1.23	2.29	2.12	2.45
Urban area	1.54	1.34	1.73	1.46	1.16	1.77
Suburban area	1.57	1.47	1.67	1.12	1.03	1.20
Southern area	1.93	1.60	2.26	1.18	1.05	1.30
Commuter area	1.53	1.34	1.73	1.31	1.20	1.42

Notes: The average competition indices were computed excluding the top 5% corresponding to outliers.
The 95% confidence interval (CI) of the mean is provided.
Figures are weighted.
Source: CIS (2004–2006) and CIS (2006–2008).

Annex 4-A2: Balancing of the sample and population by functional regions

	Sample rate (Sr)	Population rate (Pr)	P(Sr<Pr)	P(Sr>Pr)
2004-2006				
Luxembourg City	0.31	0.33	0.348	0.652
Urban area	0.14	0.14	0.515	0.485
Suburban area	0.24	0.23	0.581	0.419
Southern area	0.16	0.15	0.587	0.413
Commuter area	0.15	0.16	0.462	0.538
2006-2008				
Luxembourg City	0.30	0.31	0.420	0.580
Urban area	0.13	0.13	0.511	0.489
Suburban area	0.25	0.24	0.563	0.437
Southern area	0.12	0.09	0.711	0.289
Commuter area	0.20	0.23	0.291	0.709

Notes: the null hypotheses that the sample is under or over-represented for a specific region are tested.
Source: CIS (2004–2006 and 2006–2008).

Annex 4-A3: Sectors descriptions

Sectors	Nace rev1.1	Obs.
High and medium high-tech industries	24, 29, 30-35 (35.1 excl.)	101
Medium low-tech industries	23, 25-28, 35.1	119
Low-tech industries	15-22, 36-37	110
Gas and electricity	40, 41	23
Wholesale and commission trade	51	133
Transport and communications	60-64	179
Financial intermediation	65-67	123
Computer activities	72	90
R&D – engineering and consultancy – technical testing and analysis	73, 74.2, 74.3	80

Source: CIS (2004–2006) and CIS (2006–2008).

Annex 4-B: Descriptive Statistics

	Obs.	Mean	Std. Dev.	Min	Max
Dependent variable					
$l-(g_1-\pi)$	958	0.07	0.43	-1.47	2.16
Including:					
Employment growth (l)	*958*	*0.15*	*0.30*	*-0.44*	*1.71*
Sales growth d.t. old products (g1)	*958*	*0.15*	*0.39*	*-1.00*	*1.78*
Industry price indices (π)	*958*	*0.07*	*0.07*	*-0.01*	*0.29*
Independent variables					
Sales growth d.t. new products (g_2)	958	0.10	0.26	0.00	1.96
Process inn. only	958	0.07	0.26	0.00	1.00
Organ. inn. only	958	0.20	0.40	0.00	1.00
Process inn.	958	0.30	0.46	0.00	1.00
Organ. inn.	958	0.46	0.50	0.00	1.00
Small-sized firm	958	0.73	0.44	0.00	1.00
Medium-sized firm	958	0.21	0.41	0.00	1.00
Large-sized firm	958	0.05	0.23	0.00	1.00
Group firm	958	0.45	0.50	0.00	1.00
2006–2008	958	0.51	0.50	0.00	1.00
High and medium high-tech industries	958	0.05	0.21	0.00	1.00
Medium low-tech industries	958	0.08	0.27	0.00	1.00
Low-tech industries	958	0.10	0.30	0.00	1.00
Gas and electricity	958	0.01	0.10	0.00	1.00
Wholesale and commission trade	958	0.20	0.40	0.00	1.00
Transport and communications	958	0.21	0.41	0.00	1.00
Financial intermediation	958	0.18	0.38	0.00	1.00
Computer activities	958	0.09	0.29	0.00	1.00
R&D – Engineering and consultancy – Technical testing and analysis	958	0.32	0.47	0.00	1.00
Luxembourg City	958	0.13	0.34	0.00	1.00
Urban area	958	0.24	0.43	0.00	1.00
Suburban area	958	0.12	0.32	0.00	1.00
Southern area	958	0.19	0.40	0.00	1.00
Commuter area	958	0.32	0.47	0.00	1.00
Specialisation	958	1.47	1.09	0.02	11.38
Competition	958	1.84	1.61	0.26	6.71
Additional instruments					
Increased range of goods or services	958	1.10	1.35	0.00	3.00
Customers as information sources	958	0.89	1.21	0.00	3.00

Source: CIS (2004–2006) and CIS (2006–2008).

Annex 4-C: Correlation table

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
l-(g_1-π) (1)	1.00									
Sales growth d.t. new products (g_2) (2)	0.44	1.00								
Process inn. only (3)	-0.02	-0.14	1.00							
Organ. inn. only (4)	-0.19	-0.24	0.28	1.00						
Process inn. (5)	0.13	0.29	0.41	-0.13	1.00					
Organ. inn. (6)	0.01	0.22	0.05	0.50	0.32	1.00				
Small-sized firm (7)	0.08	0.01	-0.01	-0.03	-0.19	-0.17	1.00			
Medium-sized firm (8)	-0.04	-0.03	0.02	0.06	0.04	0.03	-0.75	1.00		
Large-sized firm (9)	-0.05	0.04	0.00	-0.05	0.26	0.22	-0.41	-0.27	1.00	
Group firm (10)	-0.09	0.10	0.00	-0.02	0.20	0.18	-0.34	0.20	0.22	1.00
2006–2008 (11)	0.01	-0.07	0.08	0.02	0.05	-0.07	0.03	-0.01	-0.02	0.00
Luxembourg City (12)	-0.02	0.03	-0.01	0.00	0.11	0.11	-0.08	0.04	0.08	0.09
Urban area (13)	0.01	-0.01	-0.01	0.01	0.05	0.03	0.00	-0.02	0.03	0.03
Suburban area (14)	0.00	0.07	0.00	0.01	0.02	0.07	0.00	0.00	-0.01	0.02
Southern area (15)	-0.01	-0.06	-0.02	0.06	-0.13	-0.04	0.00	0.00	-0.02	-0.04
Commuter area (16)	0.03	-0.05	0.03	-0.08	-0.08	-0.19	0.09	-0.03	-0.10	-0.12
Specialisation (17)	-0.07	-0.04	0.01	0.03	0.01	0.05	-0.16	0.01	0.21	0.07
Competition (18)	0.02	-0.02	0.05	-0.03	0.05	-0.01	0.11	-0.04	-0.10	0.00
Increased range of goods or services (19)	0.22	0.46	0.14	-0.28	0.63	0.34	-0.20	0.02	0.27	0.23
Customers as information sources (20)	0.22	0.43	0.14	-0.24	0.61	0.36	-0.22	0.06	0.25	0.25

	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
2006–2008 (11)	1.00									
Luxembourg City (12)	0.00	1.00								
Urban area (13)	-0.02	-0.26	1.00							
Suburban area (14)	0.01	-0.38	-0.22	1.00						
Southern area (15)	-0.06	-0.26	-0.16	-0.23	1.00					
Commuter area (16)	0.07	-0.31	-0.18	-0.27	-0.18	1.00				
Specialisation (17)	-0.02	-0.24	0.00	0.06	0.14	0.10	1.00			
Competition (18)	-0.05	0.29	0.18	-0.19	-0.12	-0.18	-0.47	1.00		
Increased range of goods or services (19)	-0.01	0.15	-0.01	0.06	-0.12	-0.13	0.03	0.04	1.00	
Customers as information sources (20)	0.00	0.09	0.00	0.07	-0.11	-0.08	0.05	0.00	0.80	1.00

Source: CIS (2004–2006) and CIS (2006–2008).

Annex 4-D: Propensity to belong to the peripheral area according to a firm's characteristics before and after reweighting

	(3.1)		(3.2)		(3.3)		(3.4)	
Peripheral area	logit (before)	logit (after)	logit (before)	logit (after)	logit (before)	logit (after)	logit (before)	logit (after)
Group firm	-0.45**	0.00	-0.44**	-0.01	-0.42**	0.00	-0.32	0.06
	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.20)	(0.30)	(0.29)
Medium-sized firm	-0.19	0.05	-0.15	0.07	-0.17	0.06	-0.09	0.08
	(0.19)	(0.19)	(0.19)	(0.20)	(0.19)	(0.20)	(0.27)	(0.28)
Large-sized firm	-0.75***	0.06	-0.59*	0.14	-0.61**	0.02	-1.17***	0.02
	(0.28)	(0.30)	(0.31)	(0.33)	(0.30)	(0.32)	(0.43)	(0.44)
% higher-educated employees	-0.18	0.03	-0.15	0.09	-0.09	0.05	-0.49	0.06
	(0.42)	(0.43)	(0.42)	(0.43)	(0.42)	(0.44)	(0.64)	(0.65)
Labour productivity	-0.26	0.10	-0.26	0.11	-0.24	0.07	-0.13	0.07
	(0.21)	(0.23)	(0.20)	(0.23)	(0.21)	(0.23)	(0.27)	(0.28)
High and medium high-tech industries	1.79***	-0.09	1.87***	-0.04	1.93***	-0.05	1.52***	-0.07
	(0.39)	(0.38)	(0.40)	(0.40)	(0.40)	(0.39)	(0.57)	(0.54)
Medium low-tech industries	2.51***	-0.04	2.60***	0.00	2.58***	0.01	2.38***	-0.08
	(0.41)	(0.41)	(0.42)	(0.42)	(0.41)	(0.41)	(0.59)	(0.56)
Low-tech industries	2.32***	-0.05	2.39***	0.00	2.33***	-0.07	2.30***	0.01
	(0.43)	(0.42)	(0.44)	(0.42)	(0.43)	(0.42)	(0.64)	(0.61)
Wholesale and commission trade	1.83***	-0.03	1.88***	0.01	1.87***	-0.03	1.73***	-0.04
	(0.39)	(0.38)	(0.40)	(0.39)	(0.40)	(0.39)	(0.60)	(0.56)
Transport and communications	1.82***	0.03	1.85***	0.06	1.81***	0.03	1.62***	0.00
	(0.38)	(0.38)	(0.39)	(0.38)	(0.38)	(0.38)	(0.58)	(0.55)
Computer activities	0.53	-0.01	0.54	0.02	0.58	0.04	0.36	-0.01
	(0.47)	(0.49)	(0.46)	(0.49)	(0.45)	(0.49)	(0.78)	(0.84)
Process inn. only	-0.06	-0.10	-0.04	-0.12	-0.13	-0.10	-0.44	
	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.35)	(0.55)	
Organ. inn. only	-0.33	0.02	-0.36	0.02	-0.44*	0.01	-0.16	
	(0.24)	(0.24)	(0.24)	(0.24)	(0.24)	(0.24)	(0.31)	
Involved in R&D			-0.44	-0.11				
			(0.32)	(0.33)				
% of R&D personnel			2.32	0.24				
			(1.42)	(1.69)				
Product new to market					-0.68**	0.01		
					(0.32)	(0.31)		
% of product new to market					0.78	-0.48		
					(1.40)	(1.18)		
Constant	-0.19	0.05	-0.15	0.07	-0.17	0.06	-0.09	0.08
	(0.19)	(0.19)	(0.19)	(0.20)	(0.19)	(0.20)	(0.27)	(0.28)
Pseudo R^2	0.14	0.00	0.14	0.00	0.15	0.00	0.14	0.00
Observations	935[1]	935	936	936	936	936	467	468

[1] 4 units were dropped following the application of common support.

Source: CIS (2004–2006) and CIS (2006–2008).

Chapter 5 : The impact of a firm's location within a metropolitan region on employment growth in an economic downturn: An examination taking into account a firm's innovativeness

1. Introduction

Innovation activity and more precisely product innovation is assumed to support employment growth. Recent empirical evidence, taking into account sales from new firms, support this theoretical assumption (Harrison *et al*. 2014) even during a downturn (Dautel *et al*. 2014). What does a firm's local environment bring in such a time? Does it sustain a firm's employment growth the way a firm's involvement in product innovation does? The extent of positive externalities provided by the environment of firms was put to the fore a century ago: "the mysteries of the trade become no mysteries; but are as it were in the air" (Marshall 1920). More recently, economists have shown the importance for firms of sustaining their absorptive capacity and link access to external knowledge to firms' in-house resources, and especially R&D (Cohen and Levinthal 1989). Others scholars, following Zahra and George (2002), have highlighted that other areas could develop a firm's absorptive capacity and have made the distinction between potential and realised absorptive capacity. All this suggests close links between a firm's in-house resources, its knowledge embodied in new products, and the realised advantages that a firm extracts from its local environment, amongst other things.

Empirical evidence shows that new products support employment, even if a productivity/efficiency effect with respect to their sales is assumed (Harrison *et al*. 2014). On the other hand, operating in central/concentrated areas requires labour productivity sustained by agglomeration effects (Helsley and Strange 2001) and/or spatial sorting, therefore assuming a labour-saving effect. Do changes in firms' economic conditions modify these findings? A recent study dedicated to the effect of new products during a downturn supports a positive response (Dautel *et al*. 2014). Firms facing negative net growth in sales were found to exhibit an increasingly elastic employment policy with respect to their sales from new products, due to rigidity in their employment policies during a downturn, while those with still positive net growth in sales were increasing such elasticity above one, taking advantage of available labour opportunities. The specific impact of agglomeration effects in times of growth versus a downturn remains to be explored. It may depend on the features of agglomeration effects and therefore on the following critical issues: Are the different micro-determinants supporting employment in the same way regardless of economic growth? Are the agglomeration economies dynamic? What is the importance of sorting? These points are usually examined according to the framework of different local labour markets. As such a framework is questionable for our case study, at least during a downturn, we also considered the poaching hypothesis (Combes and Duranton 2006a) focusing on adjustments within a single local market based on the local opportunities/costs that firms face. Such a hypothesis assumes that workers are partly holders of the firm's knowledge. Moreover, the firm's involvement in innovation activity, which is assumed to support its growth, is not random across space and may be enhanced during a downturn. It should therefore be taken into consideration.

Our aim was to use available firm-level data so as to adequately disentangle firms and local effects. Based on two waves of the Community Innovation Survey carried out in Luxembourg, our empirical strategy was to extend the Harrison *et al*. (2014) model dealing with the impact of product and process innovation on firm-level employment growth by taking into account a firm's location and varying economic conditions. So as to define economic conditions we considered both a firm's overall economic outlook and their specific success on the product market. For the former two specific reference periods corresponding to growth (2004-2006) or downturn (2008-2010) were considered. For the latter, a distinction was made according to whether firms are successful or not on the product market. Mixing both led us to split firms into four groups. Such a split leads to an important issue. A firm's likelihood of success should differ during a downturn due, firstly, to selection conditioned by a firm's characteristics and, secondly, to the enhancement or decrease of a firm's innovation activity induced by its strategy. Potential sample selection/endogeneity of the groups' settings, therefore, had to be controlled. In order to do so, a reweighting approach was used (see Busso *et al*. 2014, Hirano *et al*. 2003) leading basically to the creation of pseudo-populations during a downturn with characteristics in line with times of growth. Such an approach will be extended so as to deal with an additional issue, *i.e.* the rather unbalanced demand shock according to sector already found in other studies (*e.g.* Groot *et al*. 2011, Simon 2014), while sectoral specialization is not random across space. Basically, huge, unbalanced shocks according to sector are likely to hide some potential local effects due to a high correlation between location and sectoral specialization. To release this correlation firms were successively matched according to the sectoral specialization of the central and peripheral areas, those being the two spatial areas considered in this study.

The second section reviews the existing literature, a third section presents the data and descriptive statistics while a fourth one describes our empirical strategy. A fifth section is then dedicated to the empirical results and their discussion. A final section concludes.

1. Theoretical framework

2.1 Features of the agglomeration effects across local labour markets

According to scholars, firms invest in order to develop their absorptive capacities (Cohen and Levinthal 1989) as well as with the aim to be located in specific areas close to other players, including customers. However, firm location choice does not depend only on new knowledge access. According to the micro-determinants of agglomeration effects, firms co-locate so as to enhance the following properties: sharing, matching, learning (Duranton and Puga 2004). Additional contributions dedicated to providing empirical evidence for these micro-foundations have extended this list by considering *e.g.* home market effects or rent-seeking (Rosenthal and Strange 2004). Even if these sources are diverse, a Marshallian equivalence was suggested, as they are supposed to support urban growth in the same way (Duranton and Puga 2004, Rosenthal and Strange 2004).

However, assuming that firms have to heavily readjust their workforce during a downturn, puts to the fore labour pooling, considered as the main determinant of agglomeration of industries (Rosenthal and Strange 2001), explaining according to Papageorgiou (2014) 35% of wage premiums in the case of the US. Labour pooling is examined through two research tracks, labour pool sharing and workers (better) matching (Rosenthal and Strange 2004, Puga 2010). According to the first one, workers and firms are confronted with specific risks moderated by their location. A large concentration of workers and firms is assumed to enhance workers' firm-to-firm transfers and as such to reduce the impact of positive and negative shocks. Overman and Puga (2010) provide sectoral empirical evidence for this mechanism by highlighting that sectors experiencing high volatility are more spatially concentrated, while Ellison *et al*. (2010) show that this mechanism could work equally well across sectors to the extent that firms employ workers with similar skills. The second track highlights that firms/workers can readily change employees/employers. A lower coordination cost is assumed increasing the probability that a worker is matched to the adequate firm and the right task (Glaeser 1996). The micro-foundations of both better matching (Berliant *et al*. 2006) and a higher quality of matching (Helsley and Strange 1990) was exhibited. Some also conjecture lower search costs (Wheeler 2001, Sato 2001) or the decreasing monopsony power of firms and bargaining power of unions, making labour markets more competitive and encouraging investments in the human capital of workers (Glaeser 1996). Insofar as a firm could take advantage of both higher likelihood of matching and better quality of match when growth returns, one may assume that, when facing a negative demand shock during a downturn, the firm is less likely to retain its employees (lower stickiness). Such behaviour is not assumed in more sparse areas. The labour pooling sharing mechanism also suggests higher firm-to-firm mobility in more spatially concentrated areas. In addition, the existence of better matching before any slowdown could lead one to presume reduced opportunities due to the liquidation of other firms, *i.e.* reduced opportunities of hiring employees with skills unavailable to the firm, while increased opportunities may arise in more sparse areas. All this suggests that labour-saving adjustments should prevail in concentrated areas.

Another important feature of agglomeration effects is its potentially dynamic nature and the relative importance of selection in local productivity gaps. So far a static phenomenon has been presumed. So as to consider this, we examined the wage premium literature which is informative with respect to the productive advantages offered by big cities while firm-level productivity and wages were found to exhibit similar elasticity with respect to city size (Combes *et al*. 2010). Glaeser and Maré (2001), completing Henderson (1997), have provided an important empirical contribution, reporting wage premiums for long-time incumbent workers in big cities, and a still existing premium when they move to other locations. However, they do not address the mechanism that induces these spatial gaps. At least three sources of spatial productivity gap have to be examined. The first one is the spatial sorting of more productive workers (Combes *et al*. 2008). The second one is the static advantage provided by location as highlighted by the micro-foundations, with the exception of learning (see Puga 2010 for a review). The third one is the dynamic advantages offered by big cities enhancing experimentation and learning (Glaeser 1999, Duranton and Puga 2001) and providing, as such, opportunities to accumulate more valuable experience. An additional one is the selection of more productive firms or entrepreneurs (Combes *et al*. 2012a). Recent empirical evidence does not converge with respect to the relative importance of the three sources. De la Roca and Puga (2014) highlight the primacy of static and dynamic gains (learning mechanism), with sorting playing a minor role. Their results are consistent with the Baum-Snow and Pavan model (2012). In addition, according to their findings, the added value of experience is greater for high-skilled workers. Conversely, D'Costa and Overman (2014) find no evidence of an urban wage growth premium, sorting playing the major role. However, ensuring a clear assessment of those sources is challenging as they are not assumed to be independent. Complementarity between skills related to sorting as well as agglomeration effects are highlighted by Glaeser and Resseger (2010). Andersson *et al*. (2014) also report evidence that the extent of agglomeration effects depends on the routinized nature of the job.

2.2 The poaching hypothesis

All the previous arguments suggest mobility across local labour markets. The peculiar geographical scope of our study is, therefore, an important one to examine. Duranton and Overman (2005, 2008) found a peculiar spatial range for labour market pooling (less than 50 km). Using a similar definition to the one in the UK and Italy suggests from two to five local labour markets in our case (see Dautel and Walter 2014). But those may still be questionable in our small area. An alternative approach to the labour pooling argument that assumes mobility across labour markets is the poaching argument. According to Combes and Duranton (2006a) a firm's location choice results from the trade-off between pooling advantages and poaching costs. They also assume that knowledge is partly embodied in workers and that workers accumulate human capital on the job. As such they provide a new understanding of wage premiums: firms raise their own employee wages to decrease poaching while employees take advantage of knowledge accumulation. A dynamic wage premium is therefore assumed. To provide foundations for the accumulation of human capital on the job they refer to the labour literature on workers' flows across firms. According to Rosen (1972), younger workers optimally choose jobs that offer low wages but a fast acquisition of human capital. When reaching maturity, these workers recoup their investments by switching to occupations with fewer learning opportunities. Following this framework, one may assume that young and inexperienced workers move to an agglomeration to increase their knowledge thus leading firms in peripheral areas to be more restricted in their hiring (competition for workers in frictional labour markets is assumed).

But what happen in downturns? One may note the similarity between opportunities offered to large firms detailed by Moscarini and Postel-Vinay (2012) and those operating in central areas: both are more productive, pay more and can successfully poach workers from other firms not benefiting from the same opportunities. One may assume, therefore, that the employment trend highlighted for large firms (Moscarini and Postel-Vinay 2012) is also true for firms from the central/concentrated areas: large (central) firms attracting employment create more jobs when employment is below trend, and conversely, destroy more jobs when employment is above trend. Following this assumption, an enhanced labour-saving effect may be expected in times of downturn for firms from the central/concentrated areas.

2.3 Innovation activity and employment growth in time of downturn

An abundant literature deals with the effect of innovation activity on employment growth that goes beyond firm-level analysis and quantitative impact and distinguishes between product and process innovation (see Pianta 2005 for a review). Harrison *et al*. (2014) provide a theoretical model dealing with sales from new products in which the productivity/efficiency effects (labour-saving effects) of new products are assumed (elasticity of new sales with respect to new products lower than one). Different papers have already used this framework (Dachs and Peters 2014, Hall *et al.* 2008, Crespi and Zuniga 2012, Mairesse *et al*. 2011).

During a downturn firms are assumed to be compelled to heavily readjust their workforce, taking into account their success on the product market, the features of their labour forces and opportunities arising from the liquidation of rival firms. A productivity/efficiency effect from new products is therefore no longer assumed. According to a transaction cost perspective, when a firm is faced with a negative demand shock the higher the human capital of the staff is, the less likely the firm will be inclined to re-adjust its employment. Indeed, following this framework, hiring costs are higher for innovative firms than non-innovative ones (Rossi-Lamastra *et al*. 2011), firstly because of higher screening costs, and secondly because of higher training costs, with full benefits only apparent in the long run (Williamson 1981). Moreover, because of the importance of secrecy in innovative firms, they need to retain employees in order to avoid the kind of employee turnover that engenders high appropriability hazards (Oxley 1997). A downward stickiness of their employment elasticity with respect to their sales from new products is therefore assumed for firms with negative net growth in sales.

Moreover, the liquidation of firms and the readjustment of their labour force may give opportunities to other firms to attract available workers that match their skills requirements well. Such reallocation is enhanced by a lower opportunity cost of time and resources (Gali and Hammour 1993, Hall 1991, Aghion and Saint-Paul 1998). Such a reallocation process is assumed for innovative firms regardless of the business cycle (Bauer and Bender 2004). Indeed, to complete the setting of new or updated technologies, firms may choose between hiring new employees or training the incumbent ones (Mortensen and Pissarides 1998). Where the adoption costs are higher relative to the job creation costs, firms will destroy the old jobs and hire new workers with the necessary skills to work with the new technology and/or the new organisational environment. Following the lower opportunity cost of time and resources hypothesis, a time of crisis should, therefore, increase job reallocation toward innovative firms.

Moreover, one should notice that firms' innovation activity is likely to induce the endogeneity of their success on the product market as far as the enhancement of a firm's product innovation activity is assumed to increase its success on the product market (with potential cannibalization of old products) while process or organizational innovations may decrease its costs. In addition, it has to be highlighted that innovation activity is clearly focused on the central area before the downturn (Dautel and Walther 2014). One may hypothesise that such non-randomness may favour innovation activity in either the central area, assuming a path dependence process, or in the peripheral area, hypothesizing increasing opportunities of new products/processes for those firms with infrequent innovations. All this suggests, therefore, that one consider innovation activity as at least a potential moderating factor in the relation between firms' location and firms' employment growth.

3. Data and descriptive statistics

3.1 Data

In order to examine the present research question two waves of the Community Innovation Survey (CIS) carried out in Luxembourg and providing firm-level data of innovation activity, employment growth, firms' sales, - including those from new products, - and control variables were used. Our analysis focused on the 2008-10 wave reflecting a downturn, while the 2004-06 wave was used to provide a benchmark (growth period) and to control for potential sample selection/endogeneity biasing of the 2008-10 results.

Outcome variable

Our outcome variable is firm-level employment growth over three years (the beginning of 2008 to the end of 2010). So as to deal with our research question a distinction was made between firms with positive and negative net sales, net meaning that deflated sales were considered. Firms are indeed assumed to face different opportunities according to their respective success on the product market.

Explanatory variables

Three main variables are assumed to induce firms to readjust their employment during a downturn: a firm's new product success, their productivity and local externalities. New product success, which is assumed to induce a labour-saving effect at a time of growth, was proxied by the percentage of sales from new products. Labour productivity was considered in our specification as a control variable (description to follow). So as to deal with local externalities a dummy variable highlighting a firm's location in central or peripheral areas was considered[19]. Such a variable is assumed to reflect local externalities, including productive advantages net of local costs, with the peripheral areas as the baseline. The measurement of this externality is restricted by all other factors controlled in the specification (firms' characteristics are not spatially random). Following the poaching hypothesis, this variable may be more specific, reflecting the trade-off between pooling advantages and poaching costs. The aim of this variable is therefore to reflect the overall impact of a firm's local conditions on hiring and firing behaviour. Under the assumption that all is due to sorting, this variable should not appear as significant in the full model but significant in a very simple setting, not taking into account either employees' skills (first sorting) or a firm's advantageous characteristics (firms sorting). Our discussion will focus on this variable.

Control variables

As control variables, we first retained a firm's differentiating characteristics which are not spatially random and likely to impact employment growth. Our aim was to restrain our dummy variable of central location to a firm's externalities (productivity is assumed to be "in the air"). Those variables are: belonging to a group, firm's size, firm's sector, skills of employees (7-level categorical variable [0; 6] according to the share of employees with higher education), and firm's absolute and relative labour productivity. In addition to firm's productivity (sales per head) this latter may matter with respect to similar firms. To reflect it, the quantile of a firm's labour productivity with respect to its own sector (nace two digits) was considered. A firm's labour productivity aims to reflect

[19] Basically, we accommodate the five spatial units used by Dautel and Walther (2014) based on an aggregation of municipalities (Local Administrative Unit 2 level according to the EU Nomenclature of Territorial Units for Statistics) according to the proportion of commuters. These units reflects a centre-periphery dynamics on the basis of a monocentric vision of the nation state. We split them in two types: central areas (Luxembourg City, The Luxembourg Urban area, The Suburban area) and peripheral areas (The South area, The Commuter area).

the labour resources that firms may plan to secure during a downturn (downward stickiness) or enhance in case new opportunities arise at a lower cost. The involvement in product innovation with additional types of innovation were also considered, process innovation only and organizational innovation only. Moreover, we included two additional variables usually dedicated to controlling for the relative importance of agglomeration effects: specialization and competition. The specialization index was measured by the location quotient for the location and industry in which the responding firm is active (based on its Nace 2-digit code). The competition index relates to the inverse of firm size in a particular location and industry (Nace 2-digits) and to the inverse of firm size in the national economy in that sector.

3.2 Descriptive statistics

In 2008-10, employment growth did not differ much by area insofar as the examination does not focus on product innovative firms (Table 5-1). It seems more negative in peripheral areas than in the central area when negative net sales firms are considered, while being more positive in the peripheral area when positive net sales firms are retained. However, only the later shift is significant for product innovative firms. The local shifts are clearer according to sales growth, at least for firms with positive net sales. Firms operating in the central area exhibit a higher growth than those from the peripheral areas, regardless of their innovation activity. However, these local shifts vanished for firms with positive net sales as far as deflated productivity is concerned. Only firms with negative net sales exhibit local shifts with respect to deflated productivity growth, such growth being more negative in the central area. This result suggests that firms facing negative demand may adjust their human resources less negatively when they are located in the central area.

The examination of the 2004-06 period highlights a clearer spatial shift, especially for firms with positive net sales. Employment growth is higher for product innovative firms with positive net sales from the central area. These firms also exhibit a higher deflated productivity growth in line with a labour-saving effect. Firms from the central area with negative net sales appear, as in 2008-10, to have more negative net sales than those from the peripheral area.

Table 5-1: Growth of employment and sales by location (2008-10 and 2004-06).

	2008-10				2004-06			
	g - π<=0		g - π>0		g - π<=0		g - π>0	
	Central	Periph.	Central	Periph.	Central	Periph.	Central	Periph.
Employment growth								
All firms	-1.1	-5.7	18.2	11.6	2.0	-1.9	17.8	20.3
Non-innovators	-1.5	-6.2	12.4	10.1	4.0*	-1.5	21.7	17.3
Prod. innovators	0.2	-4.7	24.1*	13.1	-1.1	-6.6	16.6**	29.6
Sales growth								
All firms	-22.9	-19.4	28.1***	15.0	-6.1	-5.0	41.7***	30.7
Non-innovators	-21.6	-18.8	19.0*	11.3	-8.8	-4.3	35.4	26.4
Prod. innovators	-23.6	-22.6	33.1**	17.1	-3.6	-4.4	44.1	34.8
Of which :								
Old products	-36.3	-43.7	9.1**	-8.0	-23.0	-16.0	12.6	-3.2
New products	12.6	21.2	23.9	25.1	19.3	11.5	31.5	38.1
Deflated productivity growth								
All firms	-24.5**	-15.3	13.9	11.8	-15.7*	-10.1	17.0***	6.8
Non-innovators	-22.0	-13.6	13.2	12.1	-18.9	-10.5	10.8	6.2
Prod. innovators	-27.4	-20.0	16.1	7.7	-12.0**	-1.4	19.0***	0.4
Observations	163	54	182	120	108	50	227	101

Source: CIS (2004-2006) and CIS (2008-2010). Author's calculation.
Notes: Figures are weighted
***, **, * significant at 0.01, .0.5 or 0.1.

The peculiar characteristics of firms according to area (spatial sorting) may play a role in the lower spatial shift found in 2008-10. In addition, characteristics for firms with positive and negative net sales may differ in 2008-10 due to sample selection or endogeneity of net sales. Table 5-2 is set up to provide some clues for this second point.

Table 5-2: Firms' characteristics by net sales growth and period

	Entire sample			Firms with negative net sales growth (g - π<=0)			Firms with positive net sales growth (g - π>0)		
	2008-10	2004-06	t-test	2008-10	2004-06	t-test	2008-10	2004-06	t-test
Central area	0.70	0.68		0.79	0.64	***	0.60	0.72	***
Group	0.49	0.46		0.56	0.28	***	0.44	0.55	**
Medium	0.24	0.23		0.26	0.18	*	0.22	0.25	
Large	0.05	0.05		0.08	0.04	**	0.04	0.06	**
Skilled employees	2.9	2.72		3.39	2.47	***	2.52	2.84	
Labor prod.	0.33	0.32		0.34	0.3		0.31	0.33	
High and medium high tech industries	0.05	0.05		0.05	0.06		0.05	0.04	
Medium low-tech industries	0.08	0.09		0.05	0.08		0.1	0.09	
Low-tech industries	0.09	0.1		0.04	0.18	***	0.12	0.06	***
Wholesale and commission trade	0.22	0.2		0.18	0.27	**	0.26	0.16	**
Transport and communication	0.18	0.21		0.14	0.07		0.21	0.29	*
Financial intermediation	0.13	0.2	**	0.21	0.17		0.08	0.22	***
It activities	0.13	0.08	**	0.15	0.05	**	0.11	0.09	
R&D – engineering and consultancy – technical testing and analysis	0.09	0.07		0.15	0.11		0.04	0.05	
$g_1 - \pi$ *(net sales growth)*	-0.02	0.06	***	-0.31	-0.2	***	0.19	0.2	
g_2 *(net sales growth due to new products)*	0.08	0.12	***	0.06	0.07		0.09	0.15	**
Process inno. only	0.07	0.06		0.09	0.06		0.06	0.06	
Organ. inno. only	0.21	0.2		0.22	0.17		0.2	0.22	
Observations	548	490		232	157		316	333	

Source: CIS (2004-2006) and CIS (2008-2010). Author's calculation.
Notes: Figures are weighted
***, **, * significant at 0.01, .0.5 or 0.1 according to two sample t-test between 2004-06 and 2008-10.

Few gaps arise between a firm's characteristics in 2004-06 and 2008-10 when we do not split firms according to their positive or negative net sales (Table 5-2). Only g2 (net sales growth due to new products), and affiliation to the financial or IT sectors, show differences between 2004-06 and 2008-10. However, a distinction made according to a firm's success on the product market highlights clear gaps between both periods. In line with other studies showing that the demand shock was more severe in some sectors, sectoral affiliation in finance and transport and communications appears to have fostered negative net sales in 2008-10, while operating in the wholesale trade and low-tech industries favoured positive net sales in 2008-10. In addition, belonging to a group, as well as operating in the central area, having skilled employees or being of large size, appears related to negative net sales for 2008-10. Innovation activities do not differ much between both periods and net sales. As firms' incentives may vary by area a further examination of innovation activity by area is opportune (Table 5-3).

Table 5-3: Innovation activity by firm success on the product market, location and period

	Central area				Peripheral area			
	$g - \pi <= 0$		$g - \pi > 0$		$g - \pi <= 0$		$g - \pi > 0$	
	2008-10	2004-06	2008-10	2004-06	2008-10	2004-06	2008-10	2004-06
Product innov.	46.9	48.8	47.3	50.7	29.9*	16.2	23.1	30.6
Process innov. only	9.6	8.4	4.2	5.7	7.8	2.9	9.2	6.1
Organ. innov. only	26.0*	15.1	24.7	22.3	10.8	20.1	15.4	18.9
Sales from new pdt (g_2)	5.9**	9.4	11.3*	16.0	6.3**	1.9	5.8	11.7
Nb of obs.	163	108	182	227	54	50	120	101

Source: CIS (2004-2006) and CIS (2008-2010). Author's calculation.
Notes: Figures are weighted
***, **, * significant at 0.01, .0.5 or 0.1 according to two sample t-test between 2004-06 and 2008-10.

The involvement in product innovation and process innovation only is rather similar between 2004-06 and 2008-10 for firms from the central area. Only those facing negative net sales appear to stand out through an increasing focus on organizational innovation only in 2008-10. Our descriptive results suggest more variation for firms from the peripheral area, especially those with negative net sales. However, only product innovation for negative net sales firms appears significantly more frequent in 2008-10 than in 2004-06. This last result may suggest two hypotheses. The first one is that firms from these areas introduced new products on the market with the aim of better responding to what customers wanted during a downturn, without, however, succeeding to reach positive net sales (endogeneity of net sales). According to the second one, firms from this area usually characterized by both product innovation and positive net sales were still involved in product innovation in 2008-10, but were less successful on the product market (sample selection of firms).

The examination of sales from new products highlights clearer differences between 2008-10 and 2004-06. New sales are significantly lower for firms from the central areas regardless of their net sales. For the peripheral areas, the higher sales in new products in 2008-10 compared to 2004-06 has to be highlighted. This result supports either endogeneity or sample selection arising for 2008-10 between positive and negative net sales.

Table 5-4: Firms characteristics by area

	2008-10		
	Central	Periph.	t-test
Group	0.59	0.27	***
Medium	0.25	0.22	
Large	0.06	0.04	
Skilled employees	3.33	1.96	***
Labor prod.	0.37	0.24	***
High and medium high tech industries	0.05	0.06	
Medium low-tech industries	0.05	0.16	***
Low-tech industries	0.06	0.16	***
Wholesale and commission trade	0.21	0.26	
Transport and communication	0.16	0.24	**
Financial intermediation	0.20	0.00	***
It activities	0.17	0.04	***
R&D – engineering and consultancy – technical testing and analysis	0.10	0.06	*
Observations	345	174	

Source: CIS (2008-2010). Author's calculation.
Notes: Figures are weighted
***, **, * significant at 0.01, .0.5 or 0.1.

In addition to innovation activity, a firm's characteristics are also assumed to greatly vary by area (Table 5-4). The examination of the 2008-10 wave is clearly in line with such an assumption (Table 5-4). A close relationship between firms' location and firms' characteristic is observed. This is particularly the case for belonging to a group (0.59 in the central area vs 0.27), skills of employees (3.33 vs 1.96), labour productivity

(0.37 vs 0.24) and some knowledge intensive services activities such as finance (0.27 vs 0.0), IT (0.17 vs 0.04). This relationship may induce potential multicollinearity leading to large standard errors, this being all the more problematic as the number of observations is rather small.

4. Empirical strategy

We assumed that firms' success on the product market, as well as firms' innovation activity, may support firm-level employment growth. Taking both into account led us to focus on firm's sales from new products. Harrison *et al*. (2014) have developed a model devoted to such an analysis while taking into account the potential endogeneity of sales from new products. Our aim was to extend this model in order to derive empirical evidence with regard to our research question *i.e.* the impact of location in an economic downturn. To provide clear findings, comparison with growth periods for which a labour-saving effect is assumed was made. Let us first describe the set-up of the original model before focusing on our three main extensions to deal with our research question.

Harrison *et al.* (2014) model

In their original model, Harrison *et al.* (2014) decompose employment growth into four main components: the growth rate of old products (y1), the growth rate of new products (y2), the introduction of process innovation (pc) and an overall random disturbance (u). This relationship can be presented as follows:

$$l = \alpha_0 + \alpha_1 pc + y_1 + \beta y_2 + u \qquad \text{(V.1)}$$

Based on this equation, employment growth can be impacted by: i) the average efficiency growth of the production of old products (α_0 for non-process innovators and α_1 for process innovators); ii) the growth rate of old products, where, following the original model, the coefficient of y_1 is equal to one, and iii) the relative impact of new products (β) and the real output growth due to new products (y_2).

It is important to note that the y_1 coefficient is hypothesized to equal 1 (corresponding to long-term expectations, see Basu *et al*. 2005), leading to put to the fore three parameters of interest: α_0 representing the average efficiency growth in the production of old products, α_1 the process innovation effect (where pc=1), and β, the relative efficiency of the production of new products.

However, two main issues have to be solved for the estimation of this basic model. The first one relates to the estimation of the relative effect of introducing/developing new products, corresponding to the relative efficiency of producing new products in times of growth (Harrison *et al.* 2014). To deal with it, we need to substitute growth in nominal sales by growth in real production. As firms' price are not available, corresponding industry price indices π have to be used as a proxy. In addition, $l - (g_1 - \pi)$ has to be used as the dependent variable, so as to identify an effect of innovation on employment net of (direct) compensating price variations.

The reference model becomes:

$$l - (g_1 - \tilde{\pi}_1) = \alpha_1 pc + \beta g_2 + v \qquad \text{(V.2)}$$

With:

$g_1 = y_1 + \pi_1$	*: Nominal output rate due to old products, i.e. net sales growth due to old products*
$g_2 = y_2 + \pi_2 y_2$	*: Nominal output rate due to new products, i.e. net sales growth due to new products in the period*
π_1	*: Price growth rate of old products at the firm level*
$\tilde{\pi}_1$	*: Price growth rate of old products at the industry level*[20]
$v = -E(\pi_1 - \tilde{\pi}_1) - \beta\pi_2 y_2 + u$	*: Price difference between new and old product in relation to the price of the old product*
π_2	*: Price difference between new and old product in relation to the price of the old product*

Extensions to deal with our research question:

First of all, we included in the specification a variable dealing with firms' location. To do so we basically introduced a binary variable highlighting whether or not a given firm operates in the central or peripheral area. The inclusion of this variable led to a

[20] As firm level prices are not available in the CIS data, corresponding industry price indices ($\tilde{\pi}_1$) providing form the STAN OECD output deflator database are used as proxies. In order to account for the fact that 45% of firm in our database evolve mainly on foreign markets, industry price indices calculated at the OECD level are to those firms, while industry price indices calculated at the local level are assigned to others. This allows to take into consideration, at least partly, the impact of being active on international markets (Klein *et al.* 2003).

first issue to be solved, *i.e.* its potential endogeneity with regard to the current specification. The descriptive statistics have indeed clearly shown that different firm-level characteristics are correlated with such a variable. Insofar as the residual of employment growth would be related to those observed firm-level characteristics endogeneity would arise. A quick literature review of these variables is in line with this assumption. Firstly, job polarization over time has been suggested (Goos *et al*. 2009, Autors and Dorn 2013), as well as the potential offshoring of jobs to low-wage countries by multinational companies (Harrison and McMillan 2011). Belonging to a group may as well reflect some externalities which are not strictly local to the extent that knowledge exchange may be enhanced within the group. In addition, a firm's size is usually associated with growth. Moreover, recent findings highlight that firms readjust their employment according to their labour productivity during a downturn (Dautel *et al*. 2014). All of this led us to include as control variables firms' skills, group membership, size and labour productivity. It should be noted that some potential endogeneity of the spatial variable may still exist due to unobserved firms' characteristics. An usual way to deal with it is to use panel data, which was not available in our case, so as to derive fixed effects. However, this potential issue should be less severe with our firm-level data than in the more usual analyses based on spatially aggregated data.

In addition, in order to focus on our research question, we split the sample according to whether i) firms face a period of growth or downturn and ii) display positive or negative net sales growth rates. Indeed, based on the presumption that firms may have different employment strategies according to these criteria, we argue that common macroeconomic shocks, as well as firm-specific financial situations, should be taken into account.

The model becomes:

$$l_t - \left(g_{1_t} - \tilde{\pi}_{1_t}\right) = \alpha_1 pc_t + \alpha_2 org_t + \beta g_{2_t} + \delta loc + \gamma X_t + v_t \mid g - \pi > 0 \quad \text{(V.3.1)}$$

$$l_t - \left(g_{1_t} - \tilde{\pi}_{1_t}\right) = \alpha_1 pc_t + \alpha_2 org_t + \beta g_{2_t} + \delta loc + \gamma X_t + v_t \mid g - \pi <= 0 \quad \text{(V.3.2)}$$

** t reflecting the waves: 2004-06 and 2008-10*

** loc as the central vs peripheral area dummy*

** X as additional control variables including: belonging to group, firm size, employee skills, absolute and relative productivity wrt firm's sector*

*** $g=g_1+g_2$

Given that our model might suffer from endogeneity due to the possible correlation of y_2 with productivity shock, we had to take this into account using an appropriate estimation technique. This endogeneity is all the more likely to happen during a downturn for firms adapting quickly their plans. In order to account for this error term correlation, we estimated our model using instrumental variables. In line with Harrison *et al*. (2014), three instrumental variables were used: first, we used a variable measuring whether extending the product range is considered as an important goal for the firm's innovation activity (measured on a 4 points scale; 0-3) and second whether clients are an important information source for innovation activity (4 points scale; 0-3). In addition, we considered a variable dealing with both, being involved in R&D on a permanent basis during the three years of the survey (yes/no), and conducting such R&D in firms' labs (yes/no). Our aim was to include involvement in R&D on a rather permanent basis as an instrument. Basically, it seemed reasonable to assume that those variables were uncorrelated with the error term (v_t) while being related to innovation success. We tested the strength and validity of our IVs by checking the F-statistic from the first stage regression, the Kleibergen-Paap tests on weak instruments and under-identification, the Sargan-Hansen J-Test on over-identification. These tests lead to the rejection of R&D on a permanent basis as an adequate instrument for positive net sales firms in 2008-10. Only two instruments were, therefore, used in that specific case, while three instruments were used for the remaining estimations.

Moreover, using $l - (g_1 - \pi)$ as a dependent variable is equivalent to a constrained regression with g_1 stuck at 1. Such a specification was used as such in previous papers dealing with times of growth, assuming a high rigidity of g_1 with respect to g_2, while the absolute gap between g_2 and 1 reflects the relative efficiency of the new products with respect to old products ($g_2 <= 1$). During a downturn, the higher hiring costs of innovative firms suggest that g_2 is still less sticky than g_1. However, the hypothesis of a full stickiness of g_1 ($g_1=1$) is questionable. We therefore considered, as a robustness check, a lower rigidity of g_1 for 2008-10.

Further extensions to deal with two additional issues:

Our descriptive statistics have highlighted potential sample selection/endogeneity deriving from varying economic conditions that firms have to face in 2004-06 and 2008-10 as far as firms are splitted according to their positive or negative net sales. The two subsample of firms are not any more random in 2008-10 with respect to the ones of 2004-06. Our aim is to take into account the potential impact of this non-randomness on our empirical evidence. Moreover, the correlation between location, one of our main explanatory variable, and firms characteristics has also to be considered. This second issue is all the more important that different studies highlight substantial demand switch by sectors (Groot *et al.* 2011, Simon 2014) likely in our case to hide the location effect suffering to a multicollinearity issue.

So as to control for the non-randomness induced by sample selection/ endogeneity of the two 2008-10 subsamples (g - π<=0; g - π>0) each of them was matched with their respective 2004-06 subsamples (g - π<=0; g - π>0) using common support and inverse propensity score weighting (see Busso *et al.* 2014, Hirano *et al.* 2003) so that their firms' characteristics (excluding sectoral affiliation) follow the ones of the 2004-06 subsamples. More precisely, the steps below were followed. Firstly, the dataset was split according to a firm's net sales (g - π<=0; g - π>0) before computing for each of these sets of data the propensity score that a given observation was observed for 2004-06 and then we restricted each of them to common support. This applied, renewed propensity score was computed leading to new weights[21] from which our models could be re-estimated. According to Busso *et al.* (2014), such a method is more effective than matching estimators when the overlap between the samples to be matched is good. In our case, the application of common support only led us to discard 10 and 5 firms (g - π<=0; g - π>0).

Similarly, to fade the strong link between sectoral affiliation and firms' location we split the 2008-10 sample according to firms' location (central vs peripheral area) before matching them according to either central or peripheral area sectoral affiliation. In order to do so, a similar procedure to the one described above based on inverse propensity score weighting and common support was applied providing two additional weights (one by area), which was in some cases combined with ones correcting for sample selection/endogeneity so as to take advantage of both types of corrections.

[21] The propensity score (ps) was estimated by a logit model using both firms' characteristics, net growth of sales from old product, growth of sales from new products, process innovation only (%), organizational innovation only (%). This was used to reweight firms observed in 2008-10 as such: (ps)/(1-ps). This new weight is afterwards normalized.

5. Econometric results

As a first step, we examined the 2008-10 results according to Harrison *et al* (2014) specification for firms with positive and negative net sales, including our location variable, *i.e.* location in the central area (Table 5-5), as an additional parameter. In both cases, new sales are highly significant and exhibit an elasticity greater than one. Sectoral dummies are also highly significant in line with a lower demand focused on specific sectors. Considering our two additional innovation activities, process innovation only appears to support employment only for firms with negative net sales, while organizational innovation only is never significant. Our location variable is also not significant in both cases, which may suggest that sorting of firms does not play any role in employment growth during a downturn. It should, however, be noted, that sectoral dummies have a huge impact and that they are also correlated with our location variable and may thus capture its effect.

We completed this set-up by including additional firms' characteristics as well as two spatial control variables, *i.e.* specialization and competition, in our two models. Being located in the central area does not explicitly impact employment growth in either case significantly. The inclusion of additional control variables leads to lower elasticity of employment growth for firms with negative net sales, even if it is still higher than one. Among the different control variables, only belonging to a group (positive effect), relative productivity (positive) and large size (negative) are significant for firms with positive net sales and relative labour productivity (positive) for negative net sales firms. Specialization and competition are not significant for firms with either positive or negative net sales.

To push the analysis further we controlled for sample selection/endogeneity induced by lower demand using inverse propensity score weighting (see Busso *et al*. 2014, Hirano *et al*. 2003). Such a method leads to increasing employment elasticity for negative net sales firms and conversely, to decreasing it close to one for those with positive net sales. Moreover, being located in the central areas still does not appear to impact employment growth. Process innovation only by itself does not support any more increase in employment growth of negative net sales firms. Employee's education has a negative effect on the employment growth of positive net sales firms. The significance of labour productivity remains in both cases.

Table 5-5: Examination of downturn results

	2008-10[1]						2004-06[1]	
	g - π<=0			g - π>0			g - π<=0	
	(0)	(1)	(1w[2])	(0)	(1)	(1w[2])	(2)	(2)
Central area	0.00 (0.04)	-0.04 (0.04)	-0.03 (0.06)	-0.02 (0.04)	-0.06 (0.05)	-0.03 (0.05)	0.06* (0.03)	-0.10** (0.05)
g_2	1.48*** (0.43)	1.16*** (0.34)	1.45*** (0.39)	1.18*** (0.22)	1.22*** (0.21)	1.03*** (0.18)	0.54** (0.24)	0.88*** (0.18)
Lab. prod		0.05 (0.03)	0.10*** (0.04)		-0.03 (0.03)	-0.03 (0.04)	0.00 (0.04)	0.03 (0.05)
Lab. prod/nace		0.05*** (0.02)	0.04** (0.02)		0.04** (0.02)	0.05** (0.02)	0.01 (0.02)	0.00 (0.03)
Others char.		Inc.	Inc.	Inc.	Inc.	Inc.	Inc.	Inc.
Nace	$\chi^2(7)=$ 42.15***	$\chi^2(7)=$ 40.60***	$\chi^2(7)=$ 16.42**	$\chi^2(7)=$ 29.76***	$\chi^2(7)=$ 29.61***	$\chi^2(7)=$ 44.24***	$\chi^2(7)=$ 11.68	$\chi^2(7)=$ 4.46
Specialization		0.01 (0.02)	0.00 (0.03)		-0.00 (0.02)	-0.01 (0.02)		
Competition		0.02 (0.02)	0.00 (0.02)		-0.01 (0.01)	-0.01 (0.01)		
Constant	0.45*** (0.08)	0.37*** (0.10)	0.24* (0.12)	-0.32*** (0.11)	-0.35*** (0.13)	-0.35*** (0.10)	0.25*** (0.08)	-0.09 (0.09)
Partial R^2	0.19	0.20	0.22	0.19	0.20	0.18	0.24	0.26
R^2	0.37	0.47	0.44	0.40	0.45	0.47	0.40	0.33
Observations	219	219	209	298	298	293	152	324

Source: CIS (2008-2010) and (2004-2006). Author's calculation.
***, **, * significant at 0.01, .0.5 or 0.1.
Notes: Firms with employment or sales changes > 200% or <-50% have been excluded. The number of observations differ due to the application of common support. Estimates are weighted. Robust standard errors in parentheses. Partial R^2 refers to the first stage regression.
[1] Instruments are "Increased range of goods or services", "Customers as information sources" "R&D on a permanent basis during the last three years and carried out in firm's labs".
[2] Five reweighting schemes are considered: according to firms' characteristics in 2004-06 (w), sectoral specialisation in the central (c) and peripheral area (p) and the combination of them (wp, wc).

In order to further examine our 2008-10 results we thought it opportune to compare them with the 2004-06 ones. Central location for firms with positive net sales appears negative and significant, highlighting a labour-saving effect resulting from firms' location. Conversely, central location is positive for firms with negative net sales. Such an effect is in line with employees being holders of a firm's competitiveness (poaching hypothesis or dynamic wage premium) inducing a firm to not fully readjust its employment negatively (downward stickiness). However, as far as specialisation and competition are concerned, the significance of the central area becomes weak (p=0.12 for g - π<=0; p=0.13 for g - π>0). Moreover, the elasticity of new sales is below one regardless of a firm's net sales, in line with a labour-saving effect for positive net sales firms, and with a decreasing economic activity of negative net sales firms, the latter fully assuming their lack of success. As regards the control variables, they appear of low importance in 2004-06. Only one of them is significant, *i.e.* the negative effect of belonging to a group for positive net sales firms.

It was also interesting to compare whether firms' location and new sales supported employment growth for a given period and firms net sales (g - π<=0; g - π>0) in the same way. For 2008-10, those effects diverge, being rather negative for a central location (result not significant) and rather positive for new sales (elasticity greater than one) for both negative and positive net sales. For 2004-06 the impact of a firm's location (negative effect) is rather similar to the one of firms' new sales (elasticity lower than one) as far as positive net sales firms are concerned. However, these effects still diverge for negative net sales firms, central location supporting employment growth, while new sales induce a labour-saving effect (elasticity lower than one).

So as to examine further our 2008-10 results we introduced two main kinds of modifications to our specification (Table 5-6). Firstly, we included or excluded our specialization and competition controls variables, and secondly we matched samples according to either central (c) or peripheral (p) areas sectoral specialization, in combination or not with the previous matching according to firms' characteristics in 2004-06 (w). Focusing on negative net sale firms, central location impacts employment growth only when firms are matched with the central area sectoral specialisation (1c). Employment growth becomes lower in the central area than in the peripheral area according to such a specification. The result is in line with a specific impact of labour pooling during a downturn (no Marshallian equivalence) encouraging firms from the central area to readjust their labour force, bearing in mind advantageous local pooling when growth returns. It also supports the poaching hypothesis combined with a differential employment trend between the central and peripheral areas. Indeed, even if employees are assumed to be holders of firms' competitiveness (poaching hypothesis), a more negative labour adjustment would arise in the central area, insofar as a relatively higher job creation rate would be observed in good times thanks to the attraction of workers, followed by a relatively greater destruction of jobs in adverse times (release of employment arising from poaching). However, there is no clear spatial impact arising from the specifications which were considered. It also appears that the 2008-10 results are never in line with the 2004-06 ones. In addition, new sales and central location do not support firms' employment growth in 2008-10 for negative net sales firms in the same ways.

Table 5-6: Further examination of the downturn period (2008-10) for firms with negative net sales

	(2w[1, 2])	(2wp)	(2wc)	(1p)	(1c[3])
Central area	-0.02	-0.00	-0.02	-0.03	-0.06*
	(0.06)	(0.07)	(0.07)	(0.04)	(0.03)
g_2	1.44***	1.37***	1.12**	1.34***	1.12***
	(0.40)	(0.37)	(0.51)	(0.25)	(0.24)
Other char.	$\chi^2(8)$= 16.43**	$\chi^2(8)$= 17.45**	$\chi^2(8)$= 19.12**	$\chi^2(8)$= 18.06***	$\chi^2(8)$= 23.72***
Nace	$\chi^2(7)$= 11.20	$\chi^2(7)$= 11.72	$\chi^2(7)$= 12.60*	$\chi^2(7)$= 35.28***	$\chi^2(7)$= 44.57***
Specialisation				0.02	-0.01
				(0.02)	(0.02)
Competition				0.02	0.01
				(0.02)	(0.02)
Constant	0.24**	-0.12	0.05	0.39***	0.44***
	(0.11)	(0.22)	(0.19)	(0.12)	(0.09)
Partial R^2	0.23	0.39	0.24	0.34	0.27
R^2	0.44	0.38	0.43	0.46	0.56
Observations	209	209	209	219	219

Source: CIS (2008-2010). Author's calculation.
***, **, * significant at 0.01, .0.5 or 0.1.
Notes: Firms with employment or sales changes > 200% or <-50% have been excluded. The number of observations differ due to the application of common support. Estimates are weighted. Robust standard errors in parentheses. Partial R^2 refers to the first stage regression.
[1] Instruments are "Increased range of goods or services", "Customers as information sources" "R&D on a permanent basis during the last three years and carried out in firm's labs".
[2] Five reweighting schemes are considered: according to firms' characteristics in 2004-06 (w), sectoral specialisation in the central (c) and peripheral area (p) and the combination of them (wp, wc).
[3] Underidentification; Kleibergen-Paap rk LM statistic (p-val): 0.00
Weak identification; Kleibergen-Paap Wald rk F statistic: 13.88 (max. 5% allowed IV bias: 13.91)
Hansen J test on overidentifying restrictions (p-val): 0.94

The further examination of positive net sales firms provided additional insights (Table 5-7). To the extent that specialization and competition are not included in the specification and firms' sectoral affiliation is matched with peripheral area sectoral specialization (2wp), a firm's location appears to significantly impact employment growth. A labour-saving effect arises using such a specification in line with our assumption of a specific effect of labour pooling during a downturn. Indeed, lower opportunities for hiring employees with skills unavailable to the firm were presumed in the central area compared to the peripheral area, depicted by a lower quality of the match. These firms, which are not assumed to belong to the central location, seem to take particular care of their labour productivity. They may have to do so in order to not have to move or go bankrupt. The result is also consistent with the poaching hypothesis, combined with a specific employment trend in the central area. Even if firms in this area obtained positive resources for hiring additional employees, their incentive to do so vanished insofar as they would have poached (too many) employees during a time of growth. This result is also in accordance with the 2004-06 one for the full sample of positive net sales firms, but not with the one of new sales in 2008-10 (increasing elasticity). Different roles for new sales and central location are therefore suggested. Two main arguments may support these diverging effects. Firstly, location in the central area does not just provide local spillovers, *i.e.* different micro-foundations of agglomeration effects have been suggested. Secondly, to take advantage of these spillovers, firms may have to enhance their internal resources, and only half of them are innovative in the central area over a three years reference period. Following our negative net sales results, no clear spatial effect was found according to the other specifications retained. This may suggest caution with the present findings. However, our research framework suggests that during a downturn peculiar incentives from labour pooling may be compensated by other micro-determinants of agglomeration effects (identification of the net effect of the micro-determinants), while such a compensation mechanism is not assumed in times of growth (Marshallian equivalence). In addition, the large impact of sectoral affiliation during a downturn appears to hide, in our basic set-up, the location effect.

Table 5-7: Further examination of the downturn period (2008-10) for firms with positive net sales (bis)

	(2w[1, 2])	(2wp[3])	(2wc)	(1wp)	(1wc)	(2p)	(2c)
Central area	-0.05	-0.10*	-0.07	-0.09	-0.06	-0.06	-0.04
	(0.04)	(0.06)	(0.06)	(0.07)	(0.07)	(0.05)	(0.05)
g_2	1.05***	1.59***	1.09***	1.57***	1.06***	1.30***	1.17***
	(0.18)	(0.35)	(0.27)	(0.35)	(0.27)	(0.22)	(0.20)
Other char.	$\chi^2(8)$= 19.97**	$\chi^2(8)$= 10.29	$\chi^2(8)$= 11.88	$\chi^2(8)$= 10.33	$\chi^2(8)$= 11.41	$\chi^2(8)$= 14.44*	$\chi^2(8)$= 12.06
Nace	$\chi^2(7)$= 44.49***	$\chi^2(7)$= 22.66***	$\chi^2(7)$= 29.58***	$\chi^2(7)$= 22.82***	$\chi^2(7)$= 30.10***	$\chi^2(7)$= 26.55***	$\chi^2(7)$= 27.94***
Specialisation				0.00	0.01		
				(0.03)	(0.04)		
Competition				-0.00	-0.01		
				(0.02)	(0.02)		
Constant	-0.36***	-0.41***	-0.34***	-0.41**	-0.33**	-0.37***	-0.34***
	(0.10)	(0.16)	(0.12)	(0.16)	(0.13)	(0.13)	(0.12)
Partial R^2	0.19	0.18	0.19	0.17	0.19	0.22	0.23
R^2	0.47	0.46	0.42	0.46	0.42	0.52	0.45
Observations	293	293	293	293	293	298	298

Source: CIS (2008-2010). Author's calculation.
***, **, * significant at 0.01, .0.5 or 0.1.
Notes: Firms with employment or sales changes > 200% or <-50% have been excluded. The number of observations differ due to the application of common support. Estimates are weighted. Robust standard errors in parentheses. Partial R^2 refers to the first stage regression.
[1] Instruments are "Increased range of goods or services", "Customers as information sources"
[2] Five reweighting schemes are considered: according to firms' characteristics in 2004-06 (w), sectoral specialization in the central (c) and peripheral area (p) and the combination of them (wp, wc).
[3] Underidentification; Kleibergen-Paap rk LM statistic (p-val): 0.00
Weak identification; Kleibergen-Paap Wald rk F statistic: 6.85 (max. 25% allowed IV bias: 7.25)
Hansen J test on overidentifying restrictions (p-val): 0.23

To check the robustness of our findings we firstly examined the potential impact of a more flexible adjustment of employment growth with respect to sales from old products. Indeed, the full stickiness of old products (g_1=1) is questionable during a downturn, especially for firms with negative net sales. However, insofar as g_1> 0.80 for them, and g_1>0.60 for those with positive net sales, the location effects hold. In addition, we removed our rather large financial sector from the analysis, as it exhibits the sharpest decrease in jobs in 2008-10. Using this specification, only results for positive net sales firms hold true. This may suggest that firms facing narrower negative demand were likely to have adjusted their employment according to their sales more fully. However, we cannot exclude that financial firms were following a rather specific strategy with respect to their human resources. Moreover, one may wonder about the usefulness of treating the endogeneity of new sales to the extent that this variable may be seen as a control variable only in our setting. However, without such a treatment, the elasticity of employment growth with respect to new sales decreases for negative net sales firms (g_2=1.14 instead of 1.59) leading, following on this measurement error, to our location variable becoming insignificant (p=0.34). For positive net sales firms, no clear impact arises, due to the rather stable elasticity (g_2=1.05 instead of 1.12), leading the significance of our location variable to remain similar without such a treatment.

6. Conclusion

Our results suggest the weak impact of location on employment growth during a downturn and the prevailing effect of the sectoral affiliation in line with a lower demand focus on specific sectors. Sales from new products appear as more clearly driving employment growth during a downturn with the employment elasticity with respect to new sales exceeding one. Location does not have any effect on employment growth insofar as the sample is not matched to specialization according to the peripheral or central area, thus weakening the high correlation between location and sectoral affiliation. A negative effect of central location for both negative and positive net sales, in line with a labour-saving effect, is found for two specific cases: (1) for negative net sales firms with a peripheral area sectoral specialisation while controlling for sample selection/endogeneity, (2) for positive net sales firms with a central area sectoral specialisation while controlling for the relative importance of agglomeration effects through the specialization and competition variables. These results are consistent with, firstly, the specific impact of labour pooling during a downturn (no Marshallian equivalence) which is assumed to foster a rather negative adjustment of the labour force, and, secondly, the poaching hypothesis combined with a differential employment trend between the central and peripheral areas. According to the latter, employment arising from poaching would be released during a downturn.

All this suggests that the advantages offered by location are rather dynamic, in the sense that they drastically change according to the economic conditions that firms face. As such our results are both research and policy relevant. Our findings also suggest a rather complex relationship between innovation activities, and especially product innovation and agglomeration economies, since they do not support employment growth during a downturn in the same way. To provide further insights, additional analyses should focus on different types of workers (including strategic workers), or different types of clusters of firms, bearing in mind any heterogeneity at these two levels of analysis. Moreover, peculiar attention has to be paid to the available data/studies that deal with the differential employment trend for central and peripheral areas, as assumed in this paper.

Annex 5-A1: Comparison for firms with negative net sales of firms' characteristics after reweighting

	w		wc		wp		t-tests		
	2006	2010	2006	2010	2006	2010			
	I	II	III	IV	V	VI	I/II	III/IV	V/VI
Medium size	0.17	0.19	0.06	0.11	0.07	0.10			
Large size	0.05	0.04	0.01	0.01	0.01	0.01			
Skilled emp.	2.58	2.55	2.66	2.82	1.93	2.05			
Lab. prod	0.30	0.29	0.22	0.27	0.22	0.20			
Group	0.29	0.25	0.16	0.20	0.18	0.16			
$g_1 - \pi$	-0.20	-0.19	-0.17	-0.17	-0.15	-0.13			
Proc. Inn. Only	0.07	0.06	0.05	0.06	0.04	0.05			
Org. Inn. Only	0.17	0.14	0.10	0.12	0.19	0.13			
Central area	0.62	0.62	0.31	0.48	0.39	0.40			

	wc		wp		t-tests	
	central.	periph.	central.	periph.		
	VII	VIII	IX	X	VII/VIII	IX/X
High and medium high tech industries	0.02	0.01	0.01	0.02		
Medium low-tech industries	0.02	0.02	0.10	0.07		
Low-tech industries	0.07	0.05	0.15	0.21		
Wholesale and commission trade	0.30	0.33	0.46	0.41		
Transport and communication	0.13	0.13	0.17	0.16		
It activities	0.09	0.04	0.01	0.01		
R&D – engineering and consultancy – technical testing and analysis	0.12	0.09	0.06	0.07		

Source: CIS (2008-2010) and (2004-2006). Author's calculation.
Notes: Figures are weighted
***, **, * significant at 0.01, .0.5 or 0.1.

Annex 5-A2: Comparison for firms with positive net sales of firms' characteristics after reweighting

	w		wc		wp		t-tests		
	2006	2010	2006	2010	2006	2010			
	I	II	III	IV	V	VI	I/II	III/IV	V/VI
Medium size	0.26	0.24	0.15	0.14	0.13	0.16			
Large size	0.05	0.06	0.01	0.02	0.02	0.03			
Skilled emp.	2.87	2.87	3.22	3.09	2.03	1.94			
Lab. prod	0.33	0.31	0.33	0.34	0.27	0.29			
Group	0.55	0.53	0.49	0.51	0.39	0.45			
$g_1 - \pi$	0.20	0.19	0.15	0.22	0.18	0.20			
Proc. Inn. Only	0.06	0.06	0.04	0.05	0.07	0.06			
Org. Inn. Only	0.21	0.21	0.20	0.21	0.20	0.18			
Central area	0.73	0.73	0.66	0.65	0.54	0.56			

	wc		wp		t-tests	
	central.	periph.	central.	periph.		
	VII	VIII	IX	X	VII/VIII	IX/X
High and medium high tech industries	0.01	0.05	0.04	0.02	**	
Medium low-tech industries	0.03	0.04	0.09	0.11		
Low-tech industries	0.04	0.05	0.10	0.11		
Wholesale and commission trade	0.21	0.32	0.39	0.37		
Transport and communication	0.17	0.26	0.30	0.28	*	
It activities	0.16	0.22	0.06	0.06		
R&D – engineering and consultancy – technical testing and analysis	0.04	0.05	0.02	0.00		**

Source: CIS (2008-2010) and (2004-2006). Author's calculation.
Notes: Figures are weighted
***, **, * significant at 0.01, .0.5 or 0.1.

Chapter 6 : Concluding discussion

To conclude we are going to cross-check some insights drawn from the preceding chapters, before considering potential extensions to our contribution. In line with this first point, our aim will be, firstly, to provide an overview of the effect of innovation, by area and economic cycle, before focusing on the relative contribution to employment growth from non-CIS employers. Indeed, even if CIS data provides an important contribution to our topic, if we consider that innovation activities are the engine of growth, it suffers from a potential sample selection, meaning that the link between firms' local environment, firm's involvement in innovation and employment growth may differ for these firms.

1. Impact of innovation by area and economic cycle

Four main insights can be derived from chapters 5 and 6 and the following companion paper (Dautel *et al*. 2014). The first one is that innovation supports employment growth, even if a productivity/efficiency effect is assumed. Basically, a labour-saving effect is found where the elasticity of employment with respect to sales from new products is lower than one. Such a result is found for the full metropolitan region, as well as the central or peripheral areas.

The second insight is that operating in a central/concentrated area requires labour productivity that is sustained by agglomeration effects and/or spatial sorting. The presence of agglomeration effects is found in Table 5.5 with negative dummies for Luxembourg City and the urban area (with the peripheral area as the baseline) and conversely, positive dummies for the southern area and the commuter area (with the central area as the baseline). The combination of agglomeration effects and spatial sorting is highlighted in 5.6. In addition, some shifts between the central area and the peripheral area according to, firstly local effects, secondly net contribution of product innovation, and thirdly trends in old products, also suggest specific regimes in these two areas.

The third conclusion is that innovation activity supports employment growth even during a downturn. A basic distinction was made between successful and less successful firms on the product market, as those two types of firms are assumed to readjust their human resources in different ways. Firms which stayed successful on the product market ($g- \pi >0$) were found to have a rather similar elasticity of employment with respect to sales from product innovation in times of growth (2004-06) and downturn (2008-2010). Conversely, firms unsuccessful on the product market ($g- \pi <=0$) were found to have a higher elasticity of employment during a downturn than in a time of growth (see Dautel *et al*. 2014). These results suggest that innovative firms which were unsuccessful on the product market retained their skilled employment during a downturn, a result in line with a transaction cost perspective. It also suggests that innovative firms that were successful on the product market were not taking advantage of the additional human resources available on the labour market during a downturn.

The fourth insight concerns the impact of a central/concentrated area during a downturn. The basic distinction between firms that are successful and those that are less successful on the product market is maintained to examine this issue. A negative effect of operating in the central area was found in both these cases. These results suggest that labour productivity has to be maintained (see (1.c) in Table 5.6 and (2wp) in Table 5.7). These results are in line with the poaching hypothesis or a specific impact of labour-pooling during a downturn.

2. Contribution of CIS and non-CIS employers

The previous results provide important insights regarding the cross-links between firms' success on the product market, its local environment and the overall economic outlook. However, these results have ignored firms that do not belong to the target population of the CIS survey and which are likely to display specific behaviour with respect to employment growth. Indeed, even if it appears important to focus on detailed analyses of firms likely to be involved in innovation activity, it appears equally important to derive results for firms involved in ancillary activities.

A basic examination of various results taken from different chapters can provide some insights regarding the potential differential in employment behaviour of the CIS employers and the full population of employers.

2.1. Results from different chapters

As highlighted above, CIS results show specific gaps between the central and peripheral areas. These gaps derive from both spatial sorting and the impact of agglomeration effects. However, they do not monotonically increase with the size of the local area. Basically, the results for Luxembourg City are similar to the two other parts of the central area. Conversely, the full employers' results show a clear differential between Luxembourg City and the other parts of the central area. Moreover, no clear distinction stands out between the other central areas and the peripheral areas. There is only a small distinction between these two areas according to basic sorting. In addition, while the descriptive results from the CIS firms highlight the low employment growth in the suburban area, the full population firms emphasize the best employment performance in this area. All this suggests therefore that the relative employment performance of non-CIS firms differs by area.

Table 3.9 (chapter 3) provides additional insights regarding the employment performance of sectors by area. While "other business services" stand out in the urban area, "land, transport and post" do so in the suburban area, "high-tech and medium high-tech industries" in the southern area, and "high-tech knowledge-intensive services" in the commuter area. These results highlight the lower performance of "high-tech and medium high-tech industries" in Luxembourg City. Therefore, a potential relocation of some manufacturing industries from Luxembourg City to the southern area may have arisen between 1994 and 2005. In addition, knowledge intensive industries are gaining in importance in areas close to Luxembourg City as well as in the peripheral area and some less knowledge-intensive activities are increasing in central areas in relative proximity to Luxembourg City.

In order to provide robust insights, the analyses carried out in chapter 3, based on the full population have to be extended.

2.2. Extension to chapter three

The basic question which has to be examined is about the specific role played by the employers not covered by CIS, and therefore also the following two questions: What about their specific sorting by area? And what about their specific growth by area? The first question relates to a static examination of their employment impact, while the second one relates to a dynamic examination.

In order to examine these issues, one has to make a basic distinction between employers covered by the CIS and employers not covered by the CIS. The latter are ancillary activities likely to complement activities carried out by CIS firms. Any examination of potential complementarity across areas requires to take into account the different set of activities carried out in the different areas. Among them, those with less knowledge-intensive activities are assumed to have lower multipliers effects.

Previous literature has focused on the sorting of industries and the role played by specialization/diversity in competition[22]. More recent literature has examined the sorting of workers according to skills and/or tasks and has focused on differential skill complementarity. Our extension will follow this recent literature by splitting employers according to the overall education level of their employees.

As regards differential skill complementarity, Eeckhout *et al*. (2014), and Accetturo *et al*. (2014) have highlighted extreme skill complementarity through thick tails in large cities with high and low-skilled workers being overrepresented in large cities, while average skills workers are uniformly distributed by city size. For their part, Behrens *et al*. (2014) have stressed top-skill complementarity with high-skilled workers (top assistants) enhancing the productivity of superstars and first-order stochastic dominance of talent distribution by city size. In both these cases, average workers are not assumed to differ across city size. Those findings are in line with Autor and Dorn (2013a) who assume that suppliers and consumers of in-person services, who have rather different skills, have to collocate. The latter is based on the assumption that low-skill services are non-storable and non-tradable.

[22] Indices of specialisation/diversity and competition are introduced in our chapter 2, 3 and 5, 6.

Unfortunately, due to data availability we cannot consider the approaches of Behrens *et al*. (2014) nor those of Autor and Dorn (2013a), which require individual data regarding job tasks. We can only partially follow the extreme skill complementarity set-up. While Eeckhout *et al*. (2014) make the distinction between three skill types, we will consider two groups in our case, *i.e.* high-skilled vs medium and low-skilled. As such, we will examine three types of employers, CIS employers, non-CIS employers using mainly high-skilled individuals, and non-CIS employers using mainly medium or low-skilled individuals. It has to be pointed out that, as the empirical analysis of Eeckhout *et al.* (2014) is based on 254 metropolitan areas from the US with a population above 100 000, our local areas (543 202 individuals/5 areas) are at the lower band of their case study.

In order to provide a static and dynamic examination of employment contribution, we develop two indices. The first one is the share of a given type of employer by local area[23]: $\sum_{i=1}^{j} w_{i.}$. The second one is derived from our extension of Marimon and Zilibotti (1998) model: $I_{perf_i} = Evirt_{n,t} = z_n + b_t + g_{n,t}$. It corresponds to the relative contribution to growth (I perf) of a given type of employer by local area:

$$\frac{\left(\sum_{i=1}^{j}(I_{perf_i} * w_i)\right) - \left(\sum_{i=1}^{j} w_i\right)}{\left(\sum_{i=1}^{j} w_i\right)}$$

The distinction between knowledge-intensive and less knowledge-intensive sectors not covered by the CIS are based on the POME database[24] detailing the firm-level share of workers by level of formal education. These two indices are reported in the following tables. Due to the huge focus on Luxembourg City in the financial sector we also report these indices as robustness checks, excluding this sector from the analysis.

Table 6.1 highlights that the share of knowledge-intensive firms not covered by the CIS does not vary much between the different areas, the only exception being Luxembourg City for which this share peaks. Luxembourg City also differs through the

[23] with j=5 for CIS sectors; j=2 for knowledge intensive sectors not covered by CIS; j=5 for non-knowledge intensive sectors not covered by CIS.

[24] The POME survey focusing on managerial and organisational partctices of firms has been launched in Luxembourg in 2013. This survey provides among other the share of employees by level of formal education for firms covering a broad span of sectors.

share of CIS firms. However, the exclusion of the financial sector from the analysis has a huge impact on the latter result. The share of firms covered by CIS in this area decreases and becomes close to what was observed in other areas, while the share of knowledge-intensive sectors not covered by CIS is still higher in Luxembourg City than in other areas. Conversely, the share of non-knowledge-intensive sectors not covered by CIS appears lower in Luxembourg City than in other areas.

Table 6-1: Share by areas of firms belonging or not belonging to the target population of the CIS survey.

	Luxembourg City	Luxembourg urban area	Suburban area	South area	Commuter area
Financial sector included					
Knowledge-intensive sectors not covered by CIS	0.17	0.12	0.08	0.11	0.07
Non-knowledge-intensive sectors not covered by CIS	0.28	0.61	0.50	0.53	0.58
Sectors covered by CIS	0.54	0.27	0.42	0.36	0.35
Financial sector excluded					
Knowledge-intensive sectors not covered by CIS	0.25	0.13	0.08	0.11	0.07
Non-knowledge-intensive sectors not covered by CIS	0.41	0.66	0.51	0.53	0.59
Sectors covered by CIS	0.34	0.21	0.41	0.36	0.34

Source: IGSS; author's calculations.

According to Table 6.2, the contribution to employment growth of knowledge-intensive firms not covered by the CIS appears higher in the southern and commuter areas than in the suburban area. As such, this result mitigates the insights derived from chapter 4. Moreover, and in line with Table 3.9 results, the contribution of the different types of firms is negative in Luxembourg City. The specific role played by Luxembourg City therefore only appears clearly when examining the full population of firms.

More globally, four main insights can be derived from these two tables. Firstly, no clear distinction between central vs peripheral areas arises from a static analysis. Indeed, a relatively low share of knowledge-intensive sectors is observed in the suburban area, while conversely, a relatively high share of knowledge-intensive sectors is displayed in the southern area. Secondly, no clear distinction between central vs peripheral areas stands out from a dynamic analysis, when Luxembourg City is left out of the equation. Substantial employment growth arises only in areas with a lower share, in line with a catch-up effect. Thirdly, the specific role played by Luxembourg City stands out only through the full population of employers (CIS analyses only provide a clear distinction between central and peripheral areas). Two basic results support it. Noticeable is the importance of knowledge-intensive ancillary activities in Luxembourg City. It is, however, questionable to what extent these activities are linked to the financial sector only. One could also stress the high share of knowledge-intensive sectors in the urban areas close to Luxembourg City, while a low share of CIS activities is observed in this area. Fourthly, potential complementarities are suggested across the local areas. On the one hand, a low share of sectors covered by CIS is observed in the urban area, while a relatively high share of knowledge-intensive sectors not covered by CIS appears in this area. On the other hand, a high performance in terms of growth is found in knowledge-intensive sectors in the commuter area, while CIS firms exhibit low growth in these areas. All this suggests that some knowledge-intensive sectors in the urban area and the commuter area may complement activities located in other areas. It has, however, to be stressed that there are large limitations resulting from data availability. Further distinctions may strengthen our results and provide additional insights.

Table 6-2: Relative contribution to employment growth by areas for firm belonging or not belonging to the target population of the CIS survey

	Luxembourg City	Luxembourg urban area	Suburban area	South area	Commuter area
Financial sector included					
Knowledge-intensive sectors not covered by CIS	-0.04	0.05	0.13	0.07	0.12
Not knowledge-intensive sectors not covered by CIS	-0.03	0.04	0.04	-0.02	0.03
Sectors covered by CIS	-0.03	0.05	0.09	0.09	0.00
Financial sector excluded					
Knowledge-intensive sectors not covered by CIS	-0.04	0.05	0.13	0.07	0.12
Not knowledge-intensive sectors not covered by CIS	-0.03	0.04	0.04	-0.02	0.03
Sectors covered by CIS	-0.07	0.04	0.08	0.09	0.00

Source: IGSS; author's calculations.

3. Potential additional extensions of our contribution

Two main kinds of extension to our contribution may provide further insights. A first one concerns key players. Basically, our main insights taken from our extension to chapter 3 highlight, amongst other things, firstly, the specific role played by Luxembourg City and the financial sector (a focus in Luxembourg City) when considering the full population of employers, and secondly, the potential interactions of firms operating in these areas with suppliers benefiting from lower business premises. Moreover, chapter 4 has stressed the specific role played by innovating firms in the central areas, which have potential business links with non-innovating firms operating in other areas.

In order to examine these business links, three kinds of analyses may be followed. One is about multiplier effects, another one about neighbouring effects, and a last one spatial equilibrium effects. Basically, the impact of some sectors or some kinds of firms in other sectors or kinds of firms can be evaluated (see Chapter 1, §5.3). However, as such an impact may be spatially bounded, in line with our accessibility results (chapter 2 and 3), one should also consider different kinds of distance between local players (see Boschma 2005). Moreover, the small size of the country requires that one put to the fore the spatial equilibrium effects on both sides of the border.

A second extension is about the specific impact of individual players. On the one hand, ideas may be in people (Feldman 2000). Firstly, “average researchers” have a specific role to play in comparison to other knowledge holders, such as engineers, as they should be specifically involved in knowledge creation and knowledge diffusion. Indeed, they have access to scientific networks (Murray 2004), where knowledge, even though published, tends to be bounded (Gittelman 2002). In addition, the hiring of external knowledge holders such as researchers reduces firms’ tendency to focus on in-house knowledge, by exposing them to new ideas, new practices and new fields of expertise (Henderson and Clark 1990). Secondly, star scientists are also assumed to play a specific role. Zucker and Darby (1996) have stressed their leadership as a source of intellectual capital. They show too that the externalities generated by these scientists tend to be geographically bounded. Agrawal *et al*. (2014b) show that the hiring of star scientists mainly improves the average quality of subsequent recruits.

One the other hand, the specific skills or tasks of individuals are assumed to have specific effects on their job and wage opportunities (see chapter 1 §5.2). In addition to the skill-biased versus polarization assumption, which is rather a-spatial in its basic formulation, recent contributions put to the fore local specificities. Autor *et al*. (2015) show for the US that net decline in employment derives from labour markets' exposure to Chinese imports. Moreover, technology adoption may be seen as endogenous through the demand side of local specificities. According to Beaudry *et al.* (2010) the speed and extent of technology adoption varies according to local comparative advantages. Areas with low relative prices or high relative supplies of skilled workers are therefore more likely to adopt new technologies due to the complementarity with these jobs providing a higher return from skills. Finally, Autor and Dorn (2013a) assume an equilibrium condition within local labour markets, based on the assumption that suppliers and consumers of in-person services have to collocate. It has to be pointed out that this series of formal models and evidences derive from US labour markets and are defined according to 722 Commuting Zones[25]. One may examine, focusing on our case study using smaller local labour markets, whether the size of the local areas moderates such results, bearing in mind that local players have to face the trade-off between local opportunities, including proximity to other players, and the cost of business premises operating as a centrifugal force.

Moreover, it has to be stressed that specific populations come up in our case study with a large proportion of migrants and commuters among the labour force. Basically, migrants, non-migrants or commuters are likely to have both, specific impacts on firm's innovation activity and spatial equilibrium effects, due to their own skills, their matching with the requests of local employers, and their residential location. It has to be noticed that thanks to a recent released employer-employee data-set, *i.e.* the POME survey dealing with firm's organisational practices (including firm's innovation activity) matched with social security data (IGSS), these streams of research can be tackled. Two recents papers (Dautel 2017a and Dautel 2017b) dedicated to explore these streams of research suggest among other the set-up of a homophily network among the French cross-borders, impacting both, the match

[25] Summary descriptive statistics for the population size of 741 the commuting zone according to the 1990 census data are the following: average size=335 641, median size= 94 372, minimum size=1324, maximum size=14 545 373 (see Tolbert and Sizer 1996).

between cross-border, migrant and native workers at firm-level and firm's likelihood to innovate. The abstracts of these papers are provided in the following appendices (Annex 6A1 and Annex 6A2).

Annex 6-A1: Do cross-borders workers from France, Belgium and Germany foster in the same ways firm's innovation activities? Empirical evidence from Luxembourg

This article deals with the impact of cross-border workers from France, Belgium and Germany on the likelihood of firms, operating in Luxembourg, to innovate. These three groups of workers account together for 59% of the private sector's workforce, the share of cross-border workers from France (26%) being even bigger than the share of the Luxemburgish workers (18%). The results, controlling for the potential impact of the socio-economic characteristics of the workforce, the non-randomness of firm's location, the confounding effect of firm's characteristics and using an instrumentation strategy for the share of cross-border workers, highlight the positive effect of the cross-border workers from France. A relatively high share and a lower dispersion of these workers between firms, two pieces of evidence in line with the stylized facts of the homophily literature (see Currarini et al. 2009), support this positive effect on firm's propensity to innovate. Conversely, the effect of cross-border workers from Germany is negative when controlling also for common support, while the effect of cross-border from Belgium, using usually French as a mother tongue, is rather neutral. All this suggest, on one hand, the positive effect of homophily on innovation success, and on the other hand, the language and non-language distances between the three groups of cross-border workers inducing varying supports of firm's innovation activities.

Annex 6-A2: The match between cross-border, migrant and native workers at firm-level: Empirical evidence from Luxembourg

This article deals with the match between cross-border, migrant and native workers at firm-level. In order to so, we compute residual segregation measures based on conditional Duncan index, and take advantage of employer-employee data focusing on the Luxemburgish labour market. To complete our empirical set-up, we take into account contextual factors that may mediate firm-level segregation and focus on firm-level innovation. The empirical evidence highlights the relationship between firm's innovation activity on the match between workers. We further test whether these matches are due to firms' involvement in innovation activity or their auto-selection into innovation activity. Moreover, we examine workers matching according to firms' specialization toward cross-border workers from either France, Belgium, Germany, or toward (native) Luxembourgish workers, so as to provide further understanding of the underlying mechanisms of the matches between the different groups of workers. The empirical evidence highlights the relationship, taking place at firm-level, between, on one hand, the matches between workers and, on the other hand, homophily, language transaction costs and workers' exposure to other groups.

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Vincent DAUTEL

ESSAIS SUR L'IMPACT DE L'INNOVATION SUR LA CROISSANCE LOCALE DE L'EMPLOI :

Application au Luxembourg

Résumé

Cette thèse vise à clarifier la relation entretenue entre l'innovation, la localisation des entreprises et la croissance de l'emploi. Une première partie dresse une revue de littérature et positionne nos quatre essais qui suivent. Les thèmes abordés dans cette première partie sont, le changement technologique localisé, le rôle critique des externalités, la distribution non homogène des facteurs dans l'espace, et enfin les liens entretenus entre la technologie et l'emploi. De façon à considérer ce dernier point, quatre principaux types d'analyses sont examinées, à savoir, celles à l'échelle de l'entreprise, le biais sur les opportunités d'emploi induit par le changement technologique, les mécanismes d'ajustement à des échelles agrégées, et enfin les modèles d'équilibre spatiaux. Il est cependant à souligner que nos principales contributions s'inscrivent sous le chapeau du premier élément, à savoir l'analyse de l'emploi à l'échelle de l'entreprise.

Une deuxième partie de la thèse est dédiée à l'examen du lien entre l'activité d'innovation et la localisation de l'entreprise. Une distinction est ainsi menée entre, d'une part, les caractéristiques de l'entreprise, et d'autre part, les effets d'agglomérations. Ces deux éléments apparaissent soutenir l'engagement des entreprises dans l'activité d'innovation. Une distinction supplémentaire est apportée en considérant non seulement les régions fonctionnelles, mais également l'accessibilité des entreprises au centre de gravité. Les résultats mettent en évidence que les effets d'agglomération varient au sein même de certaines unités spatiales fonctionnelles. Ils soulignent également que les activités d'innovation s'organisent autour d'un centre principal localisé près de la ville de Luxembourg.

Une troisième partie de la thèse se concentre sur la croissance de l'emploi par aire géographique, sans toutefois prise en compte de l'activité d'innovation en tant que telle. L'avantage est cependant, d'une part, de ne pas souffrir d'un biais de sélection que sont par contre susceptibles de rencontrer les micro-données de l'enquête communautaire sur l'innovation, et d'autre part, d'offrir une dimension longitudinale. Afin de modéliser les dynamiques d'emploi, nous appliquons le modèle de Marimon et Zilibotti (1998) à notre contexte infra-régional. Ce modèle offre l'opportunité d'estimer l'incidence sur la dynamique de l'emploi de variations géographiques, sectorielles et temporelles, ainsi qu'à des combinaisons de ces variations (ex : contribution sectorielle

à la croissance locale de l'emploi). Les estimations empiriques mettent en évidence la croissance plus faible dans la ville de Luxembourg et à contrario la croissance soutenue dans les deux autres aires centrales bénéficiant de la proximité au centre. Une interconnection des dynamiques d'évolution des perspectives d'emploi de ces trois aires est ainsi suggérée, soutenu par l'adoption d'économies de main d'œuvre dans l'aire la plus centrale.

Une quatrième partie combine les trois principaux ingrédients de la thèse à savoir l'innovation, la localisation des entreprises et la croissance de l'emploi. Cette partie tire avantage de données à l'échelle de l'entreprise pour intégrer l'éventuelle incidence du côté demande du marché du travail et tenir compte du tri spatial des entreprises. Quatre principaux résultats en découlent. Le premier est que l'innovation soutient la croissance de l'emploi, en dépit d'un effet productivité. Ce résultat se dégage tant pour l'ensemble de la région métropolitaine, que pour les aires centrales et périphériques prises séparément. Le second effet est qu'opérer dans l'aire la plus central/la plus concentrée requiert une productivité du travail élevé, à même d'être être soutenu par les effets d'agglomérations, et/ou un tri spatial des entreprises (points examinés plus en détail dans la partie deux). Le troisième est que l'activité d'innovation soutient l'emploi, même en temps de ralentissement économique. Les entreprises innovantes infructueuses sur le marché des produits (ventes ne couvrant pas leurs frais) apparaissent ainsi retenir en temps de ralentissement leurs employés qualifiés. Ce résultat est conforme à une hypothèse de minimisation des coûts de transaction du côté employeur. Le quatrième effet tient à l'impact de l'aire centrale/concentrée en temps de ralentissement. Un effet négatif de la localisation dans cette aire se dégage, tant pour les entreprises fructueuses, qu'infructueuses, sur le marché des produits. La recherche du maintien d'une productivité du travail élevée paraît ainsi guider les entreprises œuvrant dans l'aire centrale. Ce résultat est en adéquation avec, d'une part, l'hypothèse de poches d'emplois combinée avec des perspectives d'emploi différenciées entre les aires centrales et périphériques, et d'autre part, un effet spécifique des bassins de main d'œuvre en temps de ralentissement soutenant un ajustement négatif de la main d'œuvre.

Un dernier chapitre vise à résumer les principales contributions de la thèse, ainsi qu'à étendre la troisième partie, de manière à examiner tout à la fois le rôle spécifique pouvant être joué par les employeurs non couverts par l'enquête communautaire sur l'innovation et les complémentarités potentielles en terme de qualification entre les travailleurs opérant dans des aires géographiques voisines. Les résultats empiriques soulignent que le rôle spécifique joué par la ville de Luxembourg ne se dégage que dans les analyses portant sur l'ensemble de la population des employeurs. Par ailleurs, quelques complémentarités potentielles entre les aires locales sont suggérées.

Mots clefs: Croissance de l'emploi, innovation, activités infra-régionales, profile des entreprises, effets d'agglomération, appariement par l'inverse du score de propensité, GMM, régression polynomiale locale, économie virtuelle, Luxembourg.

Vincent DAUTEL

ESSAYS ON THE IMPACT OF INNOVATION ON LOCAL EMPLOYMENT GROWTH

Application to Luxembourg

Abstract

The thesis aims at clarifying the relationship between innovation, location and employment growth. The first part of this thesis is dedicated to provide an overall review of the literature and to arrange our four essays in additional parts. Such review focuses on the localised technological change, the critical role of externalities, the not homogeneous distribution over space, before focusing on the link between technology and employment. In order to examine such link, four main types of analyses are reviewed, *i.e.* firm-level analyses, biassed technological change, adjustment mechanisms at aggregated level, spatial equilibrium models. It has however to be noticed that our mains contributions relate mainly to the first component, *i.e.* firm level analysis.

A second part of the thesis is dedicated to examine the link between innovation activity and firms' location. A basic distinction between firm's characteristics and agglomeration effects is carried out. Both appear to support firm's involvement in innovation activity, mitigating as such firms' sorting effects. A further distinction according to functional regions and firm's accessibility is made. The results highlight that agglomeration effects may vary within a given functional unit. They stress in addition that innovation activities are set-up around one main centre located near Luxembourg City.

A third part of the thesis focus on employment growth by area regardless innovation activity. As such, the results do not suffer from any selection bias, while such a bias may be derived from analyses using the micro-data from the community innovation survey. In addition, this analysis takes advantage of the longitudinal dimension of the data. In order to modelling employment trends, we apply the Marimon and Zilibotti (1998) model in our infra-regional case. This model allows estimating variations due to geographical, sectoral and time effects or the recombination of these effects (*e.g.* sectoral contribution to regional growth). The empirical estimates highlight the lower employment growth in Luxembourg-city and the relatively high growth in the two other areas belonging to the central areas. Such findings suggest a connection between the employment prospects of these three areas, foster by labour saving effects in the most central area.

A fourth part combines the main three elements, *i.e.* innovation, firms' location and employment growth. This part takes advantage of firm-level data, to provide further details regarding the demand side of the job market and taking into account firms' spatial sorting. Four main insights derive from this part. The first one is that innovation supports employment growth, even if a productivity/efficiency effect is assumed. Such result is found for the full metropolitan region, as well as the central or peripheral areas. The second one is that operating in a central/concentrated area requires labour productivity sustained by agglomeration effects and/or spatial sorting. The third one is that innovation activity supports employment growth even in time of downturn. Innovative firms unsuccessful on the product market (sales lower than firm’s costs) retain in time of downturn their skilled employment, in line with a transaction cost perspective. The fourth one is about the effect of a central/concentrated area in time of downturn. A negative impact related to this area derive from both firms successful and firms less successful on the product market. These results suggest that firms’ operating in this area aims at maintaining a high labour productivity. These results are in line with on the one hand the poaching hypothesis combined with combined with a differential employment trend between the central and peripheral areas, and on the other hand, a specific incidence of labour pooling in time of downturn, both fostering a rather negative adjustment of the labour force.

A final chapter is dedicated to resume the main contribution of the thesis and to extend the third part in order to examine both the specific role played by employers not covered by the CIS and the potential differential skill complementarity between workers operating in neighbouring areas. The empirical results highlight that the specific role played by Luxembourg City stands out only through the full population of employers. Moreover, some potential complementarity across the local areas are suggested.

Keywords: Employment growth, innovation, intra-regional activities, firms’ profile, agglomeration effects, inverse propensity score matching, GMM, local polynomial regression, virtual economy, Luxembourg.