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Abstract
This paper aims to explore the effect of regional differences on the performance of software firms in the Netherlands. Inspired by evolutionary economics, we account for the impact of (1) co-location and sharing a local knowledge base; (2) pre-entry experience in the same or related industries; (3) being connected; and, (4) having organisational capabilities to cope with change. The outcomes of the regression analyses on data gathered among 265 software firms suggest that firms located in regions specialised in ICT have a higher innovative productivity. Spin-offs and firms with organisational capabilities also perform better, while network relationships do not affect the performance of software firms.

Keywords: evolutionary economics, agglomeration economies, innovative productivity, spin-offs, software sector
JEL classification: C42, L86, O31, R10

1. Introduction

Until recently, evolutionary economics paid little attention to geographical issues (Boschma and Lambooy, 1999). There are, however, two topics in the field of economic geography, where insights from evolutionary economics are beginning to be applied in a fruitful way. The first application concerns the literature on innovation systems (Lundvall, 1988; Nelson, 1993). Economic geographers have contributed to this body of literature, stressing the importance of knowledge externalities at the regional level (Cooke et al., 1998; Cooke, 2001). The second application concerns the spatial evolution of industries. In this literature, attention is paid to the mechanisms through which an industry evolves, by linking industry location to the process of firm entry and exit on the one hand, and to processes of knowledge creation and diffusion on the other hand (Boschma and Frenken, 2003).

In this paper, we build on both bodies of literature when explaining the innovative performance of software firms in the Netherlands. The aim of the paper is to examine the extent to which the performance of software firms is affected by regional differences. In doing so, we account for four basic factors, which may, alone or in combination, affect the innovative performance of firms. Each of these factors is strongly inspired by evolutionary thinking. Three of them concern mechanisms through which knowledge and routines are transferred from one organisation to the other, resulting in knowledge diffusion, interactive learning and innovation. These transfer mechanisms are agglomeration economies, spin-offs and networks. In doing so, we account in our empirical study for, respectively, the impact of (1) being co-located and sharing a local knowledge base, (2) having a background in the same industry (spin-offs) or related industries (experienced firms), and (3) being connected or not (networks). The fourth factor concerns organisational capabilities of firms, meaning the capacity of firms to deal effectively with a lack of required resources, such as knowledge, skills and capital.

Using regression techniques and cross-sectional data gathered by a survey among 265 software firms in the Netherlands, we examine the impact of these four basic factors, controlling for other variables, on their innovative productivity. The software sector is an interesting case. It is a relatively young sector, still characterized by relatively low entry barriers and high technological turmoil (i.e. no dominant design). In addition, the software sector is spread widely across regions in the Netherlands, although it tends to concentrate more and more in some regions in the last decade. When determining the impact of the four basic factors (including the geographical dimension) on the innovative performance of software firms, we test the following hypotheses: co-located firms perform better because they benefit from localization economies, such as knowledge externalities and a skilled labour market; firms with network relationships perform better because they provide mechanisms through which knowledge and other resources are more easily transferred; spin-offs perform better because they have more experience in the sector; and firms with dynamic organisational routines show a higher performance because they are more capable of coping with change.

This paper is organised as follows. Section 2 gives a short overview of the literature that provides explanations for the innovative performance of firms. In doing so, we discuss how geography may affect innovation, such as why knowledge spillovers may be geographically localised. As mentioned above, we present four types of explanations, each of which builds on evolutionary theory: agglomeration economies, spin-offs, networks and organisational capabilities of firms. These will be tested simultaneously in the empirical part, where we measure innovative performance in terms of innovative productivity. Sections 3 and 4 introduce the empirical case, providing information on the data sources, the main variables used in the estimation models, and the research design. Section 5 describes the empirical results of the regression analyses. Finally, some short conclusions will be given.

2. The impact of geography on innovative performance of firms

In evolutionary economics, firms are subject to bounded rationality and, consequently, are unable to gather and interpret all necessary information for optimal decision-making. They rely on routine behaviour to deal with this fundamental uncertainty. Broadly speaking, routines are organisational skills that consist for a large part of tacit knowledge, which is hard to codify. When a firm is forced to adapt its routines, the firm will base its strategy on existing routines. Since search for new knowledge goes along with a high degree of uncertainty, firms will rely and build on their existing knowledge base, which provides opportunities but also sets constraints for further improvements. As a result, knowledge accumulates incrementally within the firm, resulting in new combinations of existing pieces of knowledge, or what Schumpeter once called 'Neue Kombinationen' (Nelson and Winter, 1982).

The build-up of firm-specific competences implies that firms differ from each other. Nevertheless, firms observe behaviour of other firms and try to imitate their successful routines. Imitation of successful behaviour, however, is failure-prone, because routines partly consist of tacit components that are hard to copy. Consequently, access to new knowledge is not sufficient: effective transfer of knowledge requires a capacity to identify and exploit new knowledge. In addition, interactive learning requires effective mechanisms that bring together complementary pieces of knowledge that are dispersed among different agents (Nooteboom, 2000). As a result, knowledge does spill over from one firm to the other now and then, but only under certain conditions. Below, we discuss three mechanisms through which knowledge may spill over and diffuse from one firm to the other, that is, agglomeration economies, spin-offs and networks. To end with, we elaborate on the notion of organisational capabilities to account for the fact that firms have to cope with changes that can affect the implementation of the newly acquired knowledge in their organisation.

Agglomeration economies

Traditionally, the notion of agglomeration economies covers all advantages that can be exploited by firms when located together in a restricted area. These may arise because of the presence of a well-developed infrastructure, a thick and diversified labour market, local access to specialised suppliers and a large market, and the presence of local knowledge spillovers. It is common to make a distinction between localisation and urbanisation economies (Hoover, 1948). Localisation economies arise from a spatial clustering of economic activities in similar industries, while urbanisation economies are externalities available to local firms irrespective of the industry. Hoover and Vernon (1962), for instance, claimed that new firms with new ideas often start in urban regions, because they can find more easily a new market, and they have better access to firms that can assist in overcoming teething troubles. More recently, a distinction is made between Marshall-Arrow-Romer (MAR) externalities and Jacobs' externalities, which are derived from local knowledge spillovers available to firms within an industry (in specialised agglomerations), or to firms across a variety of industries (in diversified agglomerations), respectively (Glaeser et al., 1992).

As mentioned above, evolutionary economics is primarily preoccupied with processes behind the creation and diffusion of routines and competences within and between firms. When adding a geographical dimension, an evolutionary approach explains how co-location may stimulate the creation and diffusion of new routines and competences in a restricted geographical area, and why (different types of) agglomeration economies enable incumbent firms to perform better, as compared to non-local firms. There is increasing empirical evidence that knowledge externalities may indeed be geographically bounded. Firms in the vicinity of knowledge sources (such as universities) often take more benefit from these externalities, resulting in a higher innovative performance or productivity than firms located elsewhere (Jaffe et al., 1993; Audretsch and Feldman, 1996; Anselin et al., 1997).

Co-location provides access to information and, thus, opportunities for agents to learn via monitoring and observing local rivals, without the need for explicit interaction (Malmberg and Maskell, 2002). Co-location also stimulates the build-up of local competences. Local firms sharing and accumulating similar competences in a particular knowledge field will have a better absorptive capacity and learning ability than non-local actors. This is especially true for the effective transfer of tacit knowledge, which requires a common knowledge base, shared values and mutual understanding (Howells, 2002). Thus, simple co-location may act as a vehicle of knowledge creation and diffusion. It facilitates knowledge sharing and the creative diffusion of successful routines, in which acquired local knowledge is integrated with the firms' own knowledge base, resulting in new combinations of local knowledge.

It is useful here to distinguish between different types of agglomeration economies based on knowledge spillovers. As mentioned before, firms can learn from other local firms in the same industry (localisation economies), or from local firms in other, different industries (Jacobs' externalities). With respect to the latter type, it is claimed that regions characterised by a large variety of sectors provide not only incentives for new ideas, but also valuable resources (such as complementary capabilities) required for interactive learning (Boschma, 2004). Others have argued that regional variety as such is not beneficial, because it may involve a too great cognitive distance that impedes inter-organisational learning, due to risks of miscommunication (Maskell, 2001). Instead, some degree of related variety (a diversity of sectors that complement each other) is required, enabling local firms in complementary sectors to learn effectively from each other. Recent studies have indeed observed more than once that new industries emerge in regions, which are specialized in sectors that are technologically related (Buenstorf and Klepper, 2004). A typical example is the automobile sector that took benefit from local resources (e.g. skilled labour, specific knowledge) in related industries, such as bicycle making and coach building (Klepper, 2002; Boschma and Wenting, 2004). Consequently, related variety in a region provides access to diverse, but complementary knowledge resources that might enhance the innovative performance of local firms in complementary sectors.

Spin-offs

Recently, empirical studies have devoted attention to the successful performance of spin-offs, that is, firms that were founded by a former employee of an incumbent firm in the same industry. In many industries, spin-offs have played a key role in the growth of the sector, such as the automobile industry (Klepper, 2002), the disk drive industry (Agarwal et al., 2004), and wireless telecommunication (Dahl et al., 2003).

Evolutionary theorists regard the spin-off process as a mechanism in which routines and competences are transferred from parent firms to new firms (Helfat and Lieberman, 2002). In doing so, they associate the success of spin-off firms to the pre-entry working experience of their founders. According to Shane (2000), spin-offs inherit the routines of their parents, that is, the founders bring with them the expertise acquired in the same or a related sector, such as insights in potential business opportunities, relevant technologies, or customer demand. In addition, spin-offs may draw on relationships and contacts (with customers, employees, investors) that the founder had established during his previous job in the parent organisation (Brüderl and Preistendörfer, 1998), or they may benefit from technical, or organisational support from the parent itself. Consequently, spin-offs are more experienced than new start-ups and, therefore, are expected to outperform other types of entrants.

In a long-term analysis of the US automobile industry, Klepper (2002) even demonstrated that the survival probability of a spin-off firm is directly related to the performance of its parent, suggesting that successful parents provide superior learning environments. This transfer of successful routines between firms through spin-offs has been confirmed by a long-term study of the British automobile industry (Boschma and Wenting, 2004): success in one organisation (the parent) may indeed breed success in another organisation (the spin-off). In addition, Stuart and Sorenson (2003) suggest that prior working experience in a successful incumbent firm may also increase the reputation of the spin-off firm, providing, for instance, better access to start-up capital, employees and customers.

Thus, spin-off firms are expected to be innovative, because they can build on experience and relationships established during their previous job at parent firms that other start-ups lack. But how is geography involved? Currently, we have little understanding of how geography affects the spin-off process. What comes out of a number of recent studies is that spin-offs tend to locate near their parents almost as a rule (Klepper, 2002). This may be due to the fact that spin-offs, like any other firm, are subject to bounded rationality and, therefore, locate at places they are most familiar with. In addition, the importance of maintaining pre-established relationships with the parent organisation, or with other actors (customers, investors), will keep the founders of spin-off firms from moving out of their home region (Sorenson, 2003).

As such, the spin-off process may not only be regarded as a localised mechanism of inter-firm transfer of routines and competence, in which knowledge acquired in incumbent firm gets integrated with new ideas of former employees, resulting in new recombinations. The spin-off process also provides an alternative explanation for why knowledge spillovers may be geographically bounded. In addition, spin-off dynamics may explain why some industries cluster in space. According to Klepper (2002), not agglomeration economies, but the early concentration of a few highly successful firms, creating many successful spin-offs themselves, caused the US automobile sector to concentrate in the Detroit area.

Networks

Knowledge creation and diffusion may also be organised in network constellations. Lundvall (1988) was one of the first to recognise the importance of trust-based relationships between suppliers-users for interactive learning processes to take place. Accordingly, networks are not only mechanisms that co-ordinate transactions, but also enable the transfer of knowledge in a world full of uncertainty.

Network relationships facilitate the transfer of tacit knowledge (Gertler, 2003), that is, knowledge that cannot be written down, that is partly unconscious, that defies easy articulation and, therefore, is best acquired by interaction. It requires that exchanging partners share some basic similarities such as the same language, common ‘codes’ of communication, shared conventions and norms, and personal knowledge of each other based on a past history of successful collaboration or informal interaction. Firms involved in strong network relationships with other firms are often assumed to be more capable to adapt their product. This is especially true during the initial stage of a new industry, when firms require many interactions with customers, suppliers and other organisations, due to a lack of standardisation of the product (Markusen, 1985). In such circumstances, the required knowledge to develop and use the product is unlikely to be codified. To get insight in the needs of the customers, firms regularly meet with customers to test their product and adapt it to the specific needs of their customers. Moreover, to obtain the necessary inputs, firms have to interact with suppliers to clarify their specific demands.

As such, networks act as a mechanism for knowledge to spill over and diffuse from one firm to the other. Breschi and Lissoni (2003) have claimed that not geography causes tacit knowledge to spill over between firms, but social connectedness of people in networks does. In their view, social networks provide channels of knowledge diffusion and stimulate interactive learning among its members, recombining old and new pieces of knowledge. Networks provide effective settings through which tacit knowledge circulates and interactive learning takes place. As such, tacit knowledge is regarded as a club good that is shared between members of a community of practice (Gertler, 2003). Moreover, the difference between codified and tacit knowledge should be more viewed as a continuum (Lissoni, 2001). Most knowledge has a certain level of codification, but only a small epistemic community has access to the codebook, meaning a group of people that have mutual understanding, for instance, by sharing the jargon of a topic they work on.

Such networks do not require permanent co-location. There is nothing inherently spatial about networks and, therefore, it would be wrong to assume a priori that knowledge spillovers are spatially bounded. Although the effective exchange of tacit knowledge necessitates face-to-face contacts, this need for physical co-presence may be fulfilled by bringing people together through travel now and then (Rallet and Torre, 1999). Only when social networks are localised geographically (which they often are), knowledge spillovers circulating through networks are localised geographically as well. Sorensen (2003) has claimed that social networks even enhance spatial clustering of firms, because successful entrepreneurs make use of local social networks to recognise new opportunities and to mobilise the required intellectual, financial and human capital.

Organisational capabilities

As explained earlier, the firm-specific nature of routines and competences implies that firms differ from each other. On the one hand, it brings benefit to the firm, enabling the exploitation and further improvement of its competitive advantage. On the other hand, it may turn against the economic well being of the organisation. Levitt and March (1996) have described this situation of lock-in as a competency trap: “becoming quite good at doing any one thing reduces the organisation’s capacity to absorb new ideas and to do other things” (Lawson and Lorenz, 1999, 311). Therefore, organisations need dynamic capabilities to ensure the successful implementation of new ideas. Teece et al. (1997, 516) have defined dynamic capabilities as “… the firm’s ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments”.

Two key issues are at stake when organisations have to deal with rapid change. First, one needs absorptive capacity, in order to understand new knowledge. As mentioned earlier, knowledge accumulates in the structure of organisations, as embodied in organisational routines and procedures, providing opportunities but also setting constraints for adaptation. In a way, we have already covered for this aspect: spin-offs and well-connected firms may have a better learning ability in this respect. Second, one needs organisational capability, in order to implement and exploit the newly acquired knowledge. When dealing with change, firms are confronted with shortages of resources, such as knowledge, skilled labour, customers, etc. This is especially true during the initial stage of development of a new industry, when a supportive environment is still largely lacking (Boschma and Lambooy, 1999).

In such circumstances, firms depend strongly on their own creative capacity to provide the missing resources (such as knowledge, skills, capital, etc.) themselves (Storper and Walker, 1989). For example, new knowledge is generated by learning effects and the founding of own R&D facilities; new skills are developed by internal education or learning-by-doing; capital accumulation takes place by the reinvestment of own profits, and so on. Consequently, firms with well-developed organisational routines to overcome the lack of supportive resources, may be more capable of exploiting new opportunities, and will therefore be more innovative than firms lacking such organisational capabilities.

Conclusion

In sum, geographical differences caused by (different types of) agglomeration economies may affect the innovative performance of firms. However, besides agglomeration economies, we have distinguished three other factors: spin-offs, network relationships, and organisational capabilities. The first two factors can affect the innovative performance of firms because they provide effective channels for the transfer of knowledge and successful routines between firms. The third factor also matters, since firms with dynamic capabilities are more capable of solving problems when confronted with change. Although these three factors are of a non-spatial nature in principle, in reality, geography may still play a role. Spin-offs locate near their parent organisations, geographical proximity facilitates the establishment and maintenance of network relationships, and local firms may more easily monitor and imitate successful organisational capabilities of other local firms. However, it essential to stress that geography is not necessarily involved. It should, therefore, not be assumed beforehand: its impact on the performance of firms can only be demonstrated through empirical work.

Summarizing, we formulate the following expectations that will guide the empirical part of the paper: (1) firms in regions with similar and related industries perform better because they benefit from localisation economies, such as knowledge externalities and a skilled labour market; (2) spin-offs and experienced entrepreneurs perform better since they have more (technical and market) experience in the same or related sectors; (3) firms with network relationships (a high degree of connectivity) perform better because they provide access to knowledge and stimulate interactive learning; and, (4) firms with dynamic organisational routines perform better because they can deal more easily with change.

In our empirical analysis, we need to ensure that the effects of each factor are disentangled and separated analytically from one another, in order to account for the effect of each factor on the performance of firms. This is not to deny that the different factors may work simultaneously. As mentioned before, spin-offs may benefit from network relationships established during the previous job of the founders at the parent organisation. In addition, a location in a specialised region may enhance the organisational capability of firms, while co-location may encourage the establishment of network relationships. We account for these latter aspects in our estimation models by adding interaction effects between the different variables.

3. Data

To test these hypotheses, we have gathered cross-sectional data by a telephonic survey among 265 software firms located in the Netherlands. All firms have been interviewed twice. The first survey took place in October and November 2002, while the second extended survey was held in June and July 2003.

Since software development is not distinguished as a separate category in the NACE industrial classification, the aim of the first survey was selecting the research population. We have selected at random half of all firms with two or more fulltime employees[1] that are registered at the Chamber of Commerce at NACE codes 72101, 72102, 7220 and 7230[2]. Firms that are specialised in software development are most likely to be registered at one of these NACE codes. The selected 4,144 firms have all been approached by telephone. A large number of these firms were not eligible, because firms had quitted their activities, or they appeared not to be specialised in ICT. The first questionnaire resulted in the reactions of 1,608 ICT firms specialised in diverse activities such as software development, industrial automation, Internet services, network providers etc. In total 617 firms indicated that they develop their own software and have 2 or more employees.

This paper draws on the data collected in the second, more extended survey that was restricted to the 617 software developers that were selected in the first survey. These firms only develop software with the aim to sell the product directly on the market. Firms that develop embedded software (that is, software sold included in hardware) have been excluded from the research population, since their main activity is electronic engineering. Information has been collected concerning the innovative behaviour of the firm, the pre-entry experience of the founder, network relationships,

[1] One-man businesses that are active in these NACE codes have been excluded from our study, because previous empirical studies have showed that these firms are often not eligible. These firms are often part-time activities of persons who also work at other firms, or they never became economically active (see Bleichrodt et al., 1992).

[2] The Dutch NACE 72 code is slightly different from the European standard. The standard defines 72.1 as hardware consultancy, while in the Netherlands code 721 includes consultants concerning automation and system developers (OECD, 1998). Consequently, firms registered at NACE 72.1 in the Netherlands might develop their own software and are, therefore, included in the survey. NACE 72.2 covers consultancy activities for software and software development, and NACE 72.3 data-processing activities.

organisational capabilities and other, more general firm characteristics. The response rate was 43%, i.e. 265 firms were interviewed. This group of firms is representative for the total research population with respect to firm size, registration at NACE codes, and the location of the firms in the Netherlands.

Although the software sector consists of several sub-sectors, so-called *enterprise* software firms dominate the Dutch software sector. These firms develop software platforms or modules that are extensively customised for individual clients (Casper et al., 2004). Enterprise software firms develop enterprise resource planning (ERP), customer relationship management (CRM), groupware and systems integration, but also sector-specific enterprise tools (e.g. logistics or supply chain management tools). The Dutch software sector typically consists of firms specialised in sector-specific enterprise tools that develop software for small niche markets. They combine the development of software with providing services to support the implementation and use of their software. Consequently, our sample consists of software firms involved in similar types of activities, which are specialised in a wide diversity of niche markets.

Using the data drawn from the interviews with the entrepreneurs in the second survey, we have composed almost all variables (including the dependent variable) at the firm level. However, measuring the effect of agglomeration economies requires data on the regional level. For this purpose, we have used another dataset, the National Information System on Employment (LISA) of 2001, which consists of employment in all sectors in the Netherlands at the firm level. From this dataset, we have selected employment in NACE code 72 and aggregated those data to 40 COROP-regions, which is a regional distinction similar to the NUTS III level (see appendix 1). COROP-regions are functional regions that have been constructed to indicate regional labour markets. The LISA data have been verified with data from Statistics Netherlands on the regional level (see Netherlands Institute for Spatial Research, 2003).

4. Dependent variable and statistical method

As a proxy for the performance of software firms, we have measured their innovative productivity. Innovative performance of firms is the best proxy for this study, since we aim to test the effects of agglomeration economies, spin-offs and network relationships. As explained in section 2, these factors are assumed to facilitate knowledge spillovers that most likely contribute to the technological capability and innovative behaviour of firms.

The advantage of innovation productivity as an indicator for the innovative performance of firms is that it indicates how capable firms are in managing their R&D (Klepper and Simons, 2000).. This indicator provides insight in the efficiency of the organisational routines and competences of firms. Traditionally, R&D investments and patents are used to measure innovative behaviour of firms (Kleinknecht et al., 1996). However, R&D investment only provides information about the input and not on the efficiency of those investments. A similar comment can be given on the recently more often used indicator, the innovation output of firms, i.e. the percentage of turnover due to sales of new products. A high output is still not efficient when the firms has more invested in the innovation than has gained from it in the eventual turnover. The main disadvantage of patents is that, especially in the software sector, most innovations are not protected by patents. Consequently, patents would underestimate the innovative behaviour of these firms.

The innovative productivity of firms has been measured by dividing the percentage of turnover due to sales of new products by the percentage of fulltime employment that developed the new product. These data are drawn from three questions in the survey. Entrepreneurs have been asked if they have brought any new products on the market since 2000. Entrepreneurs who confirmed this question have been asked how many percent of their total fulltime employment contributed to develop the new product (innovation input), and what percentage of the total turnover during the last year was due to the sales of the new product (innovation output).

Firms younger than 3 years have been excluded from this analysis to avoid a bias (46 firms). The new product of these firms is often their first product and, consequently, their innovation input and output will often be 100%. Of all firms older than 3 years, 34 firms answered that they had not developed a new product since 2000, while 8 firms reported that they were still working on a new product. The latter group has also been excluded from this analysis because they could not provide any data on their output. Another 8 firms were excluded as well, because they did not respond to one of the questions on innovation input or output. The total number of firms included in our empirical analysis is 169.

Since the innovative productivity of firms cannot take a value below zero, an Ordinary Least Squares (OLS) regression model is not appropriate. An OLS regression assumes that dependent variables can take on any value and may hence result in inconsistent estimators and predictive values below the limit of zero (McDonald and Moffit, 1980). Therefore, we have used a Tobit model as an alternative. This model can handle dependent variables above (or below) some limit value. All models presented below have been estimated with maximum likelihood estimation in LIMDEP, version 8.0 (Greene, 2002). Since Tobit models do not include a R^2, we have used a modified version of the McKelvey-Zaviona[3] statistic to calculate a pseudo R^2 as recommended by Veall and Zimmerman (1994).

Using five Tobit models, we have tested the hypotheses formulated in section 2. To measure the effect of each factor, several independent variables have been included as indicators for that factor in the model. When an explanatory variable has a significant or almost significant effect (p = 0.1), the variable is kept in the model and the independent variables for the next factor are added. Besides the four factors discussed in section 2, each model also includes three control variables: the type of

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[3] $$R^2 = \frac{\sum_{i=1}^{N} (\hat{y}_i^* - \hat{y}_.^*)^2}{\sum_{i=1}^{N} (\hat{y}_i^* - \hat{y}_.^*)^2 + N\hat{\sigma}^2}$$

Where $\hat{y}_i^* = \hat{\beta}' \chi_i$ is the predicted value of the latent variable for the individuals with characteristics χ_i, $\hat{y}_.^*$ is the mean of $\hat{y}_i^*$, and $\hat{\sigma}^2$ is the estimated variance of ε_i. The numerator of the McKelvey-Zavoina R^2 is a measure of the explained variance, and the second term in the denominator is an indicator of unexplained variance.

innovation the firm developed, the number of fulltime employees, and the age of the firm. The first variable measures the strategy the firm has used to innovate. Respondents were asked if the new firm has developed a totally new product or service (radical innovation) or if the new product or service builds on existing products and services of the firm (incremental innovation). This is a dummy coded variable, in which a value of 1 equals a strategy based on the production of radically different products. The other two firm characteristics are the number of fulltime employees in the firm (as a proxy for size), and the number of years that the firm exists (as a proxy for age). All models tested negative for multicollinearity, because correlation analyses revealed that the variables included in the equations do not show too high significant statistical association (see appendix 2).

In principle, our empirical analysis deals with a multilevel problem, because potentially relevant factors are measured on two levels of analysis. Agglomeration economies are measured on the regional level, while all other variables are measured at the firm level. Many studies treat such data by using individuals as the basic unit of analysis, and link variables on the regional level to the data for individual firms. However, this might violate the homoscedasticity assumption and may result in biased regression coefficients and reduced variation. Because of deflated standard errors, explanatory variables may incorrectly show up as statistically significant, and erroneous conclusions may be drawn about their impact on the dependent variable (Snijders and Bosker, 1999). Therefore, we have tested whether the –2 log likelihood of an OLS regression is significantly higher than that of a random intercept-only model. The difference between the two models was, however, only 1, which implies that the differences between regions are not statistically significant. In other words, a multilevel analysis is not necessary.

We have considered using spatial autocorrelation techniques, however, the number of interviewed firms was too low. Nevertheless, previous empirical studies on the Netherlands have shown that knowledge spillovers are more likely to occur within a COROP-region than between these regions, since this already concerns a relatively high spatial scale (Van Stel and Nieuwenhuijsen, 2004).

5. Empirical results

This section of the paper describes the results of our empirical analysis on the effects of regional differences and firm characteristics on the innovative productivity of software firms in the Netherlands. In the first model, we only test the effect of different types of agglomeration economies. In the second, third and fourth model, we include respectively the effects of network relationships, pre-entry background of the founders (i.e. working experience in either the software sector itself, or in related ICT sectors), and organisational capabilities. In the fifth model, we test several interaction effects between the included variables. When discussing the results, we mention which independent variables have been developed and used to measure the above-mentioned factors. Table 1 gives the descriptive statistics of the used variables.

< table 1 here >

Agglomeration economies

We first consider the effect of regional differences on the innovative productivity of the Dutch software firms. As discussed in section 2, co-location of firms may stimulate the creation and diffusion of knowledge. The hypothesis we test states that *firms co-located in regions with similar and related industries perform better,* *because they can benefit from localisation economies*. We have focused on the specialisation of the labour market to test the effect of localisation economies, because high-educated and skilled employees are the main input of these firms. Previous empirical studies (Haug, 1991; Casper et al., 2004) indicated that enterprise software firms hardly have any contacts with universities and can easily obtain their necessary supplies (mainly software platforms) from a few multinationals.

The variable we use to determine the specialisation of the local labour market is a location quotient which measures the fraction of the regional employment that the ICT sector (NACE code 72) represents in that region, relative to the share of the whole industry in national employment in 2001 (see Glaeser et al., 1992). This variable is not limited to the software industry but also incorporates ICT consultancy activities. Software firms are likely to effectively learn from these firms since they have much experience with implementing ICT at customers' firms. This index is measured at the COROP level. Each individual firm gets the score assigned to the region where it is located. To measure the effect of a variety of sectors per region in general (Jacobs' externalities), we have included a variable that indicates the industrial diversity per COROP region. This diversity is measured by computing the *Gini* coefficient[4] for employment in all industries in each region. High values of *Gini* mean that employment is more unequally distributed across the economic sectors of a COROP region. To account for the effect of urbanisation economies, we have included an additional variable in the model, that is, total population per COROP region.

In model 1, we have assessed the effects of these three independent variables on the innovation productivity of the software firms while including three control variables. As shown in table 2, localisation economies has a significant and positive effect, while the indicator for both Jacobs' and urbanisation economies is insignificant. As expected, software firms located in a region with a relatively high percentage of ICT employment have a higher innovative productivity. When taking a closer look at the data, this positive effect is caused by a negative correlation between the degree of ICT specialisation of the region and the percentage of employees that worked on the new product, i.e. the innovation input ($p = 0.00$ and correlation = -0.26). In other words, software firms located in areas with a high ICT specialisation seem to be more efficient in their use of innovation inputs. However, the correlation between a location with a relatively high percentage of ICT employment and innovation output (percentage of turnover due to sales of new products) is not significant ($p = 0.125$), though it has a positive sign.

What is more, two of the three included control variables have a significant effect. As table 2 shows, the innovation strategy indeed influences the innovation productivity of firms. The negative coefficient indicates that firms that incrementally

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[4] $\text{GINI} = \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n}\left|s_{i,g} - s_{j,g}\right|$

$s_{j,g}$ = share of total employment in location j

$s_{i,g}$ = share of employment in sector g in location i

n = number of regions

adapt their products perform better than firms that introduced a radically different product. Other empirical studies on the innovation behaviour of firms found similar results (e.g., Kleinknecht et al., 1996). Nevertheless, the characteristics of the dependent variable might cause this finding. The development of a radical and complex new product takes a lot of time and customers might be more reluctant to accept it, which may cause an initially low percentage of the turnover due to the sales of that new product. Table 2 shows that firm age has a significant and negative effect on the innovation productivity of firms. In other words, younger firms perform better. The effect of firm size is not significant.

Network relationships
In section 2, we claimed networks might function as effective channels of knowledge diffusion and interactive learning, because they can provide a common knowledge base and mutual understanding and trust. In model 2, we test the following hypothesis: *software firms involved in network relationships perform better.* In the software sector, the demands of customers are the main incentive for new product development. In our survey, about 70% of all innovative firms indicated that customers are the main source for innovation. Many enterprise software firms are project-based firms that develop a specific product for one customer. During such a project, firms cooperate with other software firms that develop a complementary product (Grabher, 2002). Software development requires detailed specification of the characteristics of the product to integrate products. As a consequence, we expect regular contacts with other software firms to be beneficial. Therefore, our empirical study accounts for network relationships with both customers and competitors.

We have not accounted for relationships with suppliers and universities, because our survey showed that these relations are either standardized, or they hardly exist. To obtain the necessary technological knowledge, most entrepreneurs mention that they use the Internet or specialised magazines. Only 18 firms mentioned that they have problems finding suitable suppliers. Most entrepreneurs answer that the high standardisation of these supplies makes it possible to order the necessary supplies at the Dutch sales departments of multinationals (such as Microsoft and IBM), or on the Internet. Especially enterprise software firms hardly have any contacts with research institutes. This is less true for embedded software firms, which rely to a larger extent on technological developments and, therefore, have more contacts with technical universities.

< *table 2 here* >

To test the importance of network relationships, we have developed two independent variables using the answers of entrepreneurs on two questions in the survey. The first variable is a 1-0 dummy variable that indicates the type of relationship between the firm and its main customers. A value of 1 equals a relationship in which firms develop software together with their customers or regularly discuss face-to-face the product design to adapt it to their needs. All other firms have a pure market relationship with their customers in which they only meet when the customer obtains the product. The other variable is also a 1-0 dummy variable that indicates whether the software firm has regular contacts with other software firms: the firm gets a value of 1 if it does. Table 1 shows that in both cases, 63% of all firms are involved in such a relationship. In the second model of table 2, we have added the two variables for network relationships. Contrary to our expectations, both variables have no significant effect whatsoever on the innovation productivity of the software firms.

Pre-entry experience of the founder

As stated in section 2, the transfer of knowledge and successful routines between firms may occur through spin-off dynamics. As a result, we expect the pre-entry experience of entrants to affect the performance of software firms. Our third hypothesis to be tested states that *spin-offs and, to a lesser extent, experienced firms have a higher innovative productivity, since they have more experience in the same or related sectors*.

To be able to test the effect of the pre-entry experience of the founder, entrepreneurs have been asked whether the founder(s) of the firm had working experience and, if so, what the main activity was of their previous employer. Using these answers, two dummy-coded variables have been developed. The variable spin-off gets a value of 1 when at least one of the founders used to work in the software sector. To account for the effect of experience in related industries on the performance of the firm, as Klepper found for the television industry, the variable experience in the ICT sector has been included. A value of 1 means that one of the founders had working experience in the ICT industry but not in the software sector. From table 1, it can be seen that 31% of all founders previously worked at a software firm, while 21% of all founders used to work for another ICT firm. Our data support the comment made in section 2 that most spin-offs (60%) locate in the same region as the parent firm.

The two dummy-coded independent variables have been added in model 3. Again we have to reject our hypothesis. As table 2 demonstrates, both variables do not have a significant effect on the innovation productivity of firms, compared to other start-ups. The variable for working experience in the ICT sector even has a negative sign, and it does not contribute anything to the model ($p = 0.89$). Nevertheless, the variable spin-off has a positive effect on the performance of the software firms, and is almost significant ($p = 0.10$). Since this variable does improve the fit of the model, we keep this variable in the model.

As stated in section 2, the higher performance of spin-offs might be caused by the fact that they receive support from the parent firm. Therefore, we have tested whether spin-offs that remained contacts with the parent firm are more innovative than spin-off firms without those contacts. However, this effect is not significant. Furthermore, spin-offs that continued to receive support from the parent firm did not show a higher innovative performance than independent spin-offs. Therefore, our results tend to indicate that spin-offs mainly perform better because the founders bring with them relevant experience acquired during their previous job at the parent organisation.

Organisational capabilities

The hypothesis we test here is that *software firms with organisational capabilities perform better since they can deal more easily with changes that occur in the sector*. Although the Dutch software sector is still a relatively young sector, it went through some dramatic changes in the market situation during the last 10 years. In the second half of the 1990s, the demand for software grew enormously. During that time, an enormous shortage in supply of ICT skills occurred, and most firms were confronted with serious problems to attract and find new employees to meet the quickly rising demand. This situation completely changed after the year 2000. Many customers postponed their investments in new software packages due to the drop in economic growth and the burst of the Internet bubble. As a result, demand for software has dropped dramatically.

We assess the organisational capabilities of software firms in terms of how they coped with these two recent changes in their market situation. As a result, we are not relating the notion of organisational capability to having problems with acquiring new knowledge. This is because our survey showed that the Dutch software firms hardly have any problems obtaining the necessary technological knowledge. The Internet plays an important role in solving these problems. When firms need a specific application, they search on the Internet for a specific supplier and receive the product by (e-) mail. To solve programming problems, software programmers use the Internet to discuss their problem with specialised colleagues from all over the world on specialised Internet platforms. The high level of codification of software makes this possible (Lissoni, 2001).

In the survey, entrepreneurs have been asked whether they had problems finding new employees and getting enough customers. We have also asked if the firm had developed a strategy to deal with these problems in order to determine the urgency of the problem. We have constructed two 1-0 variables to measure the effect of organisational capabilities. The first variable indicates whether the firm had problems getting customers. A value of 1 confirms that the firm had experienced those problems and pursued a strategy to overcome them. The other variable indicates whether the firms had problems finding new employees. Again, a value of 1 means the firms had been confronted with this problem and had followed a strategy to cope with it. From table 1, we can see that 49% of all firms had problems with getting customers, and 54% of the firms had problems with finding new employees.

In the fourth model of table 2, these two variables have been added. Having problems finding new employees had no significant effect ($p = 0.13$). However, having problems with finding new customers had a significant and negative effect. As expected, software firms that were incapable of dealing with the drop in demand performed somewhat worse. Taking a more detailed look, we found a negative correlation between having problems finding new customers and the percentage of turnover due to sales of the new product ($p = 0.09$). This outcome suggests that their software products did not match demand.

Moderating effects

In model 5, we have tested whether the included variables interacted with the relation between other variables and the performance of firms. In other words, we have controlled for so-called moderating or interaction effects (Bennett, 2000). Three interaction effects had a significant effect and improved the model substantially. Even more interesting is the fact that the main effects of the explanatory variables (except for the control variables) become insignificant when the interactions effects are included in model 5. Thus, the outcomes show that our explanatory factors are interrelated and mainly in this way affect the innovative performance of firms.

The first moderating effect is that having working experience in the software sector positively affects the relation between developing a radical innovation and innovative productivity. While for software firms in general, the innovation strategy of introducing a radically different product has still a negative effect on their innovative productivity, the outcome in table 2 suggests that experienced entrepreneurs with a background in software (i.e. spin-off firms) can develop a radically new product and still have a good balance between their innovation output and innovation input. Possibly, these entrepreneurs have a better insight in market demand, or they know how to organise the development of a radically new product due to their working experience. In addition, when the interaction term is included in the model, the direct effect of being a spin-off becomes insignificant.

Second, the variable having problems with getting new customers also interacts with the relation between the type of innovation and innovative productivity. However, this variable strengthens the negative effect of developing a radically new product on the efficiency of the innovative behaviour of the firm. Thus, when a firm that has to cope with problems finding new customers develops a radically new product, the innovative productivity of the firm lowers. These software firms seem to lack good market information and develop products that do not match the demand of (potential) customers.

The third significant moderating effect shows that having problems with finding new employees interacts with the relation between localisation economies and innovative productivity. As shown in table 2, when firms have problems finding new employees, their innovative productivity is higher when they are located in more specialised regions, that is, regions with a relatively high percentage of ICT employment. The direct effect of the relative specialisation of a region becomes insignificant when the interaction term is included. In other words, a location in a more specialised region is only relevant for firms that have to deal with problems finding new employees. We already found a negative correlation between the location in a region with a relatively high specialisation in ICT employment and the innovation input. A similar correlation exists between having problems finding new employees and the percentage of employees that developed the new product ($p = 0.05$ and correlation = -0.14). In other words, both factors seem to stimulate a more efficient use of employment for the development of new products. Consequently, the firm's innovative productivity is higher when a firm is characterised by both factors.

Finally, we tested the effect of the interaction between the pre-entry experience of the founder and the network relationships of the firm. As mentioned in section 2, founders with experience in the same or related industry are more likely to have established contacts with potential customers or other ICT firms during their career. Therefore, we expected that these firms have better access to resources following from network relationships. However, the interaction effects between spin-off and both measures of network relationships are not significant.

6. Conclusion

The aim of this paper was to test whether (different types of) agglomeration economies indeed stimulate the performance of software firms, or if this effect is caused by the involvement in network relationships, the pre-entry experience of the founder, or the organisational capabilities of the firm. Our empirical study shows that localisation economies, an entrepreneurial background in the same industry, and organisational capabilities affect the innovative productivity of Dutch software firms simultaneously. The outcomes suggest that software firms are more efficient in their innovative behaviour when they are located in a region with a relatively high number of ICT employment, when the firms are founded by someone who previously worked in the software sector, and when they can deal with problems finding new employees. Network relationships do not affect the performance of firms. However, we acknowledge that we have used a relatively crude measure for the importance of network relationships that does not capture their quality. A more in-depth examination of these relationships might shed further light on how network relationships affect innovative performance of firms.

The findings concerning the impact of localisation economies throw an interesting light on the key question of how a location in a more specialised region is beneficial for firms. We found that the positive effect of localisation economies is caused by the fact that firms located in such specialised areas need significantly less fulltime employment for developing new products (i.e., a lower innovation input). The correlation between regions with high ICT specialisation and the innovation output of the firm is not significant and, therefore, these firms are indeed economically more efficient. But the question remains what causes the lower innovation input. Can such firms develop similar innovations with fewer employees because they benefit from knowledge spillovers between them and other firms located in that region? Or are ICT employees more specialised and skilled in more specialised ICT labour markets, resulting in higher productivity levels? Or are they forced to use fewer employees due to stronger competition for ICT employment in these areas? Further empirical research is necessary to answer these highly intriguing questions.

In addition, future empirical work should focus on disentangling the impact of agglomeration economies and other factors (such as spin-off dynamics) on the performance of firms. Our analysis showed that the factors have a highly interrelated effect on the performance of firms. We believe that the geographical implications of these other factors should be further explored empirically in order to get a better understanding of their impact. Such an approach would most certainly benefit from taking a more dynamic perspective, in which the spatial evolution of an industry is analysed in terms of entry (innovation), exit (selection) and diffusion (imitation) of routines and competences in a population of firms over time (Boschma and Frenken, 2003). We are only at the beginning of exploring this new, exciting field of research in economic geography.

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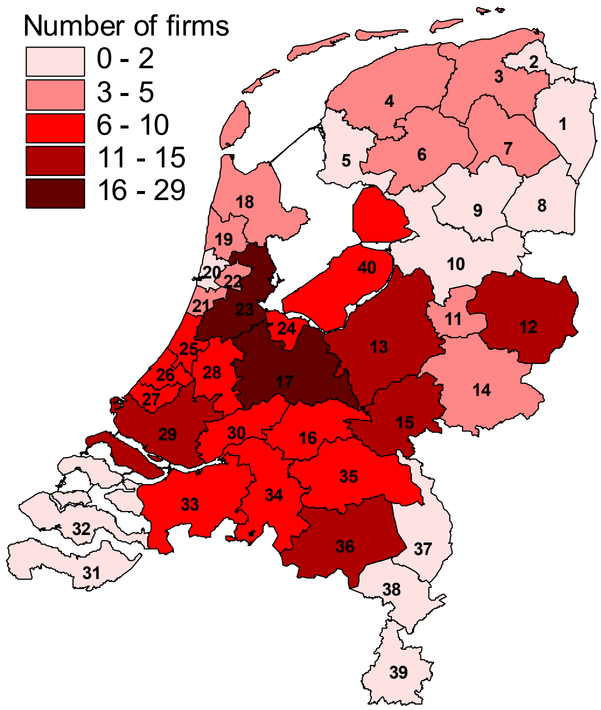
Appendix 1. Map of the 40 COROP-regions in the Netherlands and the number of software firms of the research population per region (January 2003)



1. East-Groningen
2. Delfzijl
3. Rest of Groningen
4. North-Friesland
5. South-West Friesland
6. South-East Friesland
7. North-Drenthe
8. South-East Drenthe
9. South-West Drenthe
10. North Overijssel
11. South-East Overijssel
12. Twente
13. Veluwe
14. Achterhoek
15. Aggl. Arnhem-Nijmegen
16. South-West Gelderland
17. Utrecht
18. Kop van North Holland
19. Alkmaar
20. IJmond
21. Aggl. Haarlem
22. Zaanstreek
23. Greater Amsterdam
24. Gooi and Vechtstreek
25. Aggl. Leiden
26. Aggl. The Hague
27. Delft and Westland
28. East-South Holland
29. Greater Rijnmond
30. South-East South-Holland
31. Zeeuws-Vlaanderen
32. Rest of Zeeland
33. Western North-Brabant
34. Middle of North-Brabant
35. North-East North-Brabant
36. South-East North-Brabant
37. Northern Limburg
38. Middle of Limburg
39. Southern Limburg
40. Flevoland

Appendix 2. Correlation matrix between the independent variables

Pearson product-moment correlation, one-tailed with pairwise deletion

	1	2	3	4	5	6	7	8	9	10	11
1. IT specialisation region	--										
2. log total employment region	0.39***	--									
3. Industrial diversity	0.04	0.09	--								
4. Strong relation customers	-0.09	-0.06	0.01	--							
5. Regular contact competitors	0.04	-0.00	-0.02	0.01	--						
6. Spin-off	-0.03	-0.14**	-0.11*	-0.05	0.00	--					
7. Experience in the ICT sector	0.13*	0.13**	-0.00	0.03	0.03	-0.34***	--				
8. Problems with customers	0.06	-0.07	-0.02	-0.07	0.16**	0.09	0.06	--			
9. Problems new employees	-0.03	-0.01	0.04	0.02	0.11*	0.02	0.02	-0.04	--		
10. Type of innovation	-0.09	-0.05	-0.02	0.06	-0.02	0.04	0.03	0.04	-0.12*	--	
11. Log fulltime employment	0.10*	0.09	0.04	-0.00	0.06	0.02	-0.02	0.13**	0.15**	-0.14**	--
12. Log firm age	0.05	-0.06	-0.03	-0.06	-0.03	-0.09	-0.07	-0.02	0.01	0.03	0.21***

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Table 1. Mean, standard deviation, minimum and maximum value for each variable

	Mean	Std. Dev.	Minimum	Maximum	N
1. Innovative productivity	94.6	80.12	0.00	500.00	169
2. IT specialisation by region	1.27	1.08	0.26	3.92	169
3. Industrial diversity	0.28	0.03	0.20	0.34	169
4. Population by region	633,69	384,01	104,85	1,359,64	169
5. Strong relation customers	0.63	0.48	0.00	1.00	169
6. Regular contact competitors	0.63	0.48	0.00	1.00	169
7. Spin-off	0.31	0.46	0.00	1.00	169
8. Experience in ICT sector	0.21	0.41	0.00	1.00	169
9. Problems finding customers	0.49	0.50	0.00	1.00	168
10. Problems getting employees	0.54	0.50	0.00	1.00	163
11. Type of innovation	0.26	0.44	0.00	1.00	169
12. Fulltime employment	13.49	17.00	2.00	100.00	169
13. Firm age	10.78	5.84	4.00	28.00	169

Table 2. Estimations results for the innovative productivity of software firms in the Netherlands (standard errors in parentheses) [a]

Variable	Model 1	Model 2	Model 3	Model 4	Model 5
Constant	2.509*** (0.555)	1.761*** (0.175)	1.766*** (0.161)	1.722*** (0.170)	1.783*** (0.162)
Log (IT specialization per region)	0.277* (0.156)	0.228 (0.144)	0.230 (0.144)	0.264* (0.145)	-0.005 (0.181)
Industrial diversity	-1.378 (1.502)				
Population by region	-0.130 (0.154)				
Network relationships customers		0.065 (0.096)			
Relationships with competitors		0.028 (0.096)			
Spin-off			0.173 (0.107)	0.184* (0.104)	-0.032 (0.116)
Experience in the ICT sector			-0.027 (0.122)		
Problems finding customers				-0.168* (0.095)	-0.011 (0.107)
Problems getting employees				0.141 (0.095)	-0.211 (0.160)
Spin-off x type of innovation					0.681*** (0.221)
Problems finding customers x type of innovation					-0.514** (0.210)
IT specialization per region x problems getting employees					0.323*** (0.112)
Type of innovation	-0.406*** (0.107)	-0.408*** (0.107)	-0.414*** (0.108)	-0.395*** (0.109)	-0.374** (0.163)
Log (fulltime employment)	0.216 (0.133)	0.198 (0.133)	0.187 (0.132)	0.220 (0.139)	0.167 (0.132)
Firm age	-0.016** (0.008)	-0.015* (0.008)	-0.013 (0.008)	-0.013* (0.008)	-0.015** (0.008)
Number of observations	*169*	*169*	*169*	*162*	*162*
Log likelihood	*-160.32*	*-160.89*	*-159.57*	*-152.87*	*-143.76*
-2 log likelihood	*320.6*	*321.78*	*319.14*	*305.74*	*287.52*
Sigma	*0.60****	*0.60****	*0.59****	*0.59****	*0.56****
Pseudo R^2	*0.144*	*0.133*	*0.147*	*0.214*	*0.297*

[a] Dependent variable: Log (innovative productivity + 1)

* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$