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The Effect of Regional Differences on the Performance of Software Firms in the Netherlands

by

Ron A. Boschma and Anet Weterings

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Faculty of GeoSciences
Department of Economic, Geography
University of Utrecht
P.O. Box 80.115, 3508 TC Utrecht, the Netherlands
a-weterogs@geog.uu.nl / r.boschm@geog.uu.nl

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Abstract:
In this paper, we concentrate on how evolutionary economics contributes to a better understanding of the spatial evolution of newly emerging industries. Inspired by evolutionary thinking, four types of explanations are discussed and tested in an empirical analysis of the spatial pattern of the software sector in the Netherlands.

Traditionally, agglomeration economies provide an explanation for the spatial concentration of an industry. Firms located in a cluster of similar or related sectors benefit from cost reductions, due to lower transportation costs, a thick labour market, specialised suppliers and information spillovers. An evolutionary approach on agglomeration economies provides an alternative view. It focuses explicit attention on knowledge spillovers as a vehicle of local diffusion of organizational routines or competences from one firm to the other. Such transfers of (tacit) knowledge are facilitated by spatial proximity of firms and a common knowledge base. In addition, an evolutionary approach takes a dynamic perspective on the role of agglomeration economies. During the initial stage of development of a new industry, the surrounding environment is still directed to routines and competences related to existing industries. When the new industry concentrates in a particular area to a considerable degree, a supportive environment (specialized knowledge, labour with specific skills) may gradually come into being, and localization economies may arise.

Other evolutionary mechanisms may also provide an explanation for the spatial formation of new industries. We distinguish another three of them. First of all, transfer of knowledge and successful routines between firms in an emerging industry may occur through spin-off dynamics. Secondly, (social) networks may function as effective channels of knowledge diffusion and interactive learning, because they can provide a common knowledge base and mutual understanding and trust. Thirdly, firms in new industries with organizational capabilities that can deal effectively with the lack of required resources (such as knowledge, skills and capital) may become dominant, due to selection and imitation.

Based on cross-sectional data gathered among 265 software firms in the Netherlands in 2003, we have tested which factors have influenced the innovative productivity of these firms. Using regression techniques, the outcomes suggest that spin-offs and firms with organizational capabilities perform better, while networks relations do not seem to affect the performance of software firms. Geography matters as well: software firms located in a region with a labour market with more ICT-skills show a higher innovative productivity.

Key words: Evolutionary economics, industrial location, evolution of industries, software sector, agglomeration economies, organizational capabilities, spin-off, networks
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1. Introduction

Until recently, evolutionary economics paid little attention to geographical issues. This is, perhaps, less true for two topics in the field of economic geography, where insights from evolutionary economics are beginning to be applied in a fruitful way (Boschma & Lambooy, 1999). 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 paper, we concentrate on this latter topic, explaining how evolutionary economics contributes to a better understanding of the spatial evolution of newly emerging industries.

The main purpose of this paper is to explain the spatial pattern of an industry from an evolutionary angle. We present a brief overview of the recent literature that deals with the spatial formation of new industries from an evolutionary perspective. We distinguish between four evolutionary mechanisms, which may, alone or in combination, decide where new industries will emerge in space. Three of them concern mechanisms through which knowledge creation, interactive learning and innovation may take place. These mechanisms of transfer of knowledge and successful routines are the following: agglomeration economies, spin-offs and networks. In other words, we account for, respectively, the impact of (1) being co-located (geographical proximity) and sharing a local knowledge base, (2) having a background in the same (spin-offs) or related industries (experienced firms), and (3) being connected or not (networks). The fourth factor concerns organizational capabilities of firms, meaning the capacity of firms to deal effectively with the 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 evolutionary mechanisms 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 (no dominant design), while it is spread across all regions in the Netherlands. We test our assumption that the performance of software firms is not strongly affected by regional differences. More in particular, we test hypotheses, such as: firms benefit from urbanization economies rather than localisation economies; spin-offs perform better because they have more experience in the sector; firms with dynamic organizational routines show a higher performance; and firms with network relations perform better.

This paper is organised as follows. Section 2 gives a short overview of the literature that deals with the spatial evolution of industries from an exclusively evolutionary angle (see Boschma & Frenken, 2003, for a detailed overview). We discuss four types of explanations, each of which is built on evolutionary theory: agglomeration economies, spin-offs, networks and organizational capabilities of firms. These will be tested simultaneously in the empirical part. Section 3 and 4 introduces the empirical case, providing information on the data sources, the main variables used in the estimation models, and the research design. Section 5 presents the empirical results of the regression analyses. Finally, some short conclusions will be given.

2. An evolutionary approach to the spatial evolution of industries

In evolutionary economics, firms are assumed to have 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 uncertainty. Broadly speaking, routines are organisational skills that consist of experience knowledge and tacit knowledge. 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 and experience. As a result, knowledge accumulates within the firm, due to learning from experience, trial-and-error processes and R&D activities.

Nevertheless, due to its quasi-public nature, knowledge does spill over now and then. In addition, the build-up of firm-specific competences implies that required knowledge is dispersed among many different agents and organizations. As a result, knowledge creation and learning often depend on combining diverse, complementary capabilities of different organizations (Nooteboom, 2000). We deal with three evolutionary mechanisms through which knowledge may spill over or diffuse from one firm to the other: agglomeration economies, spin-offs and networks. In this respect, we interpret the spatial evolution of new industries in terms of entry (innovation), diffusion (imitation) and exit (selection) of routines and competences in a population of firms over time, resulting in a particular spatial pattern of the new industry. In other words, an evolutionary approach pays attention to the mechanisms at work through which an industry evolves, by linking industry location to the process of firm entry and exit on the one hand, and to explicit mechanisms of knowledge diffusion on the other hand (Boschma & Frenken, 2003).

Agglomeration economies

Traditionally, agglomeration economies provide an important explanation for the spatial concentration of an industry. Firms located in a cluster of similar or related sectors are assumed to benefit from cost reductions due to lower transportation costs, a thick labour market, specialised suppliers and knowledge spillovers. New firms are assumed to select those regions due to strategies of cost minimalization (leading to more entries), while firms inside those agglomerations will perform better, as compared to non-local firms (resulting in less exits). An evolutionary approach on agglomeration economies will focus explicit attention on the local diffusion of routines and competences from one firm to the other.

Recent empirical studies have demonstrated that knowledge externalities may be geographically bounded. Firms in the vicinity of knowledge sources (such as universities) often take more benefit from these externalities, and will most likely show a better innovative performance or higher productivity, than firms located elsewhere (Audretsch & Feldman, 1996; Feldman & Audretsch 1999). Co-location of firms facilitates knowledge sharing and the imitation of successful routines. Geographical proximity provides opportunities for agents to learn via monitoring and observing local rivals, without the need for explicit interaction (Malmberg & Maskell, 2002). Moreover, local firms sharing 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, 2003). Thus, simple co-location may act as a vehicle of knowledge creation and diffusion in which external local knowledge acquired through imitation is integrated with the firms' own knowledge base, resulting in new recombinations of local knowledge.

When analyzing the spatial evolution of new industries, it is important to adopt a dynamic evolutionary perspective. Developing a new industry requires new types of knowledge, skills, capital, markets and inputs, which existing organizations and their surrounding environment cannot provide, because these are orientated towards, and committed to, previous technologies (Boschma, 1997). Moreover, the technology has not yet standardized and, consequently, firms do not have any specific locational demands. New entrepreneurs will not know beforehand what they precisely require from their environment. Producing a new major technology is surrounded by many uncertainties. Firms are still adapting their product and are not yet sure which inputs and which skills they need from their environment. Consequently, at the initial stage of the new industry, none of the regions will be able to match the requirements of the new industry. The low level of vertical disintegration at this time makes it unlikely that firms profit from specialised suppliers. Also firms are forced to train their employees in-house to develop the specific skills they need and, therefore, they profit initially little from thick labour markets. Only when the firms have adjusted the regional conditions to their demands, localisation economies might become important. Until then, the new firms can locate almost everywhere.

This mismatch does not imply, however, that new industries have complete free locational choice. Firms require employees, capital, and other inputs, which we call *generic*, instead of *specific*, conditions. Urban regions are more likely to offer such beneficial conditions. Urbanization economies (based on generic advantages of being co-located), rather than localization economies (based on specific advantages of being co-located) influence the spatial formation of new industries in their initial stage of development. In other words, the only regional factors that might affect the spatial evolution of the new industry during this stage are urbanisation economies, that is externalities following from a concentration of different types of firms and people (Jacobs 1969). Such a concentration offers new firms the opportunity to profit from a large and diversified labour pool and large potential demand. Firms can test their new products, and it is easier to find a new market or new suppliers when they are forced to change their product. Therefore, many new firms start in an urbanised region. Nevertheless, the discontinuous nature of major new technologies also offer the possibility of a location in less urbanised regions, as happened in Silicon Valley.

Since an evolutionary approach is a non-deterministic approach, it claims it is unpredictable where the new industry will locate. Contingency plays a key role: some urban regions might develop the new industry while other regions with similar conditions do not succeed to do so. *Historical factors* influence the spatial evolution of the new industry and, therefore, we can only explain that regions lacking such basic requirements are more likely to fail to generate new industries. An evolutionary approach stresses the dynamic process of regional development: a logic of self-reinforcing regional growth based on agglomeration economies is predated by an initial phase in which historical accidents are possible. As Arthur (1994) claims, once a region has attracted slightly more entrants than other regions for whatever reason, a critical threshold is passed, and only then agglomeration economies may play a dominant role, further stimulating the concentration of the industry. This explanatory framework is characterized by three characteristics of evolutionary processes: multiple possible outcomes, path dependence and irreversibility.

With the maturing of the industry, the locational demands of the firms become more specified and the windows of locational opportunity close around some dynamic areas that have developed the necessary regional conditions. Entrepreneurs have transformed and shaped the generic conditions of their environment into the specific conditions their firms require. As a result, the industry will concentrate in those more dynamic regions. Once the spatial system has emerged this phase, change will become merely marginal. The leading regions continue to stay ahead at the expense of lagging regions.

Spin-offs

There is an expanding literature that describes the growth of a new industry in terms of a sequence of firms giving birth to firms giving birth to firms, etc. This process has played an important role in the rapid growth and spatial concentration of industries like the ICT sector in Silicon Valley, the biotechnology sector in Cambridge (UK) (Keeble et al. 1999), the US automobile industry in the Detroit area (Klepper 2002), the wireless telecommunications cluster around Aalborg in Denmark (Dahl et al., 2003) and the British automobile industry in the Coventry area (Boschma & Wenting, 2004), just to name a few.

Arthur (1994) developed a stochastic firm birth model in which the probability of a new spin-off in each region is equal to the current distribution of incumbent firms across all regions (Martin, 1999). Although it displays evolutionary features like path dependence and multiple outcomes, it is not a real evolutionary model, because routines are not part of it (Boschma & Frenken, 2003). Klepper (2002) developed a different spin-off model, which takes into account evolutionary features. His model accounts for the fact that experience acquired in related industries or in the industry itself is inherited by spin-offs. In this respect, he directly relates the survival probability of a spin-off with the performance of the parent: success in one organization (the parent) is likely to breed success in another organization (the spin-off). Klepper (2002) found empirical support for this proposition. He was able to show that the spatial concentration of the automobile industry in the U.S. was mainly caused by the early concentration of a few highly successful entrants generating successful spin-offs.

Spin-offs are most likely to occur during the initial stage of the industry, due to the low entry barriers and the many market opportunities that the still unstandardised technology offers. In his study of the spatial evolution of the automobile industry in the United States, Klepper (2002) found that spin-offs had better survival opportunities than other types of entrants. According to Klepper, spin-offs inherit the routines of their parents because the founder(s) already worked in the same or a related sector. Consequently, these entrants are more experienced than new start-ups and, therefore, more likely to perform well. Once cost competition affects the survival of firms, the regions that host less successful firms will lose and the industry further concentrates in the region with successful firms.

Klepper (2002) explains the agglomeration of the automobile industry in Detroit with this model. Although automobile firms first were located scattered over the whole country, Detroit finally dominated the industry. According to Klepper, not agglomeration economies explain this spatial evolution, but a few highly successful firms, creating successful spin-offs, caused the industrial concentration. The leaders of the successful four early entrants in Detroit were extremely experienced entrepreneurs. Their spin-offs inherited their experience, which led to higher survival rates than firms located outside this city.

The only geographical factor in this model is that spin-offs are assumed to locate where their parents are based (Klepper 2002). Consequently, employees of incumbent firms will start their own firm near their parent. Thus, the spin-off process is not only 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. It also provides an explanation for why knowledge spillovers are geographically bounded. This does not imply, however, that industries in which spin-off dynamics are important, will eventually concentrate in space. On the contrary, Klepper even argues that the spatial concentration of the automobile industry might well be an extreme case. For instance, the television industry developed out of firms that were already active in the radio industry. This industry located not in one place, but largely reflected the geographic distribution of the radio producers (Klepper & Simons 2000).

Networks

From an evolutionary perspective, the role of networks is relevant when knowledge creation and diffusion is 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. He realized that networks are not only mechanisms that co-ordinate transactions, as proposed by transaction costs economics. Networks could also be seen as a kind of vehicle that enables the transfer of knowledge in a world full of uncertainty.

Network relations facilitate the transfer of tacit knowledge (Gertler 2003), that is, knowledge that cannot be written down, is partly unconscious, 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 relations with other firms and institutions are often assumed to be more capable to adapt their product to the constant changing requirements.

This is especially true during the initial stage of a new industry, when firms require many interactions with customers, suppliers and institutions, due to the lack of standardisation of the product (Markusen 1985). At this time, the product is not yet standardized and the required knowledge to develop and use the product is also unlikely to be codified. To get an insight in the needs of the customers, firms regularly meet with customers to test their product and further adapt it to the specific needs of their customers. To obtain the necessary inputs, the new firms have to interact with suppliers to clarify their specific demands.

As explained earlier, spatial proximity may facilitate the exchange of tacit knowledge. Several empirical studies, however, have demonstrated that the effects of spatial proximity are overestimated. According to Martin and Sunley (2003), the main problem of most empirical studies on knowledge spillovers is that they measure the effect of these spillovers on an aggregated level. In this way, they only suggest the existence and location of possible clusters by providing a shallow and indirect view. To really identify the relations and knowledge spillovers between firms, more low-scale empirical research is necessary.

An empirical study by Breschi & Lissoni (2002) confirms the importance of low-scale research in avoiding an overestimation of the role of geographical proximity. They showed that when social distance is included as a variable to explain co-location of citing and cited patents, geographical distances ceases to be significant. This suggests that not geography causes knowledge to spillover between firms, but social connectedness of people 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. This result reminds us of the fact that tacit knowledge is a 'club good', which is shared between members of an 'epistemic community', or 'community of practice' (Gertler, 2003). Moreover, also the meaning of tacit knowledge seems to be misinterpreted (Lissoni 2001). The difference between codified and tacit knowledge should be more viewed as on a continuum. 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 communities do not necessarily require spatial proximity. Nevertheless, since social networks are often highly localized geographically (but not necessarily), knowledge spillovers turn out to be localised geographically as well.

Dynamic organizational capabilities

As we 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 well-being of the organization (lock-in). This has been described by Levitt and March (1996) as the 'competency trap': "becoming quite good at doing any one thing reduces the organization's capacity to absorb new ideas and to do other things" (Lawson & Lorenz, 1999, p. 311). Therefore, organizations need dynamic capabilities to ensure the successful implementation of new ideas. Teece et al. (1997) have defined the notion of dynamic capabilities as "… the firm's ability to integrate, build, and reconfigure internal and external competences to address rapidly changing environments" (p. 516).

We think two issues are at stake when organizations deal with rapid change. First, one needs absorptive capacity, in order to understand new knowledge. As mentioned earlier, knowledge accumulates in the structure of organizations, 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: firms in large urban centres with a generic knowledge base, spin-offs and well-connected firms may have a better learning ability in this respect. Second, one needs organizational capability, in order to implement and exploit the newly acquired knowledge. In such circumstances, 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 lacking.

As a consequence, firms in new industries depend strongly on their own creative capacity to provide the missing resources (such as knowledge, skills, capital, laws, etc.) themselves (Storper & Walker, 1989). As the industry further evolves, firms actively shape and transform their environment to develop the specific needs they require. New knowledge is generated by learning effects and the founding of their own R&D institutes; new skills are developed by internal education or learning-by-doing; capital accumulation takes place by the reinvestment of own profits, and so on. After a while, all type of facilitating organizations will develop in the region. Specific research institutions directed to the new technology will develop, and new or adapted educational organizations will offer new education programmes. As a result, when a region hosts firms that have well-developed organizational routines to overcome the lack of supportive resources, and which have succeeded better in adapting their regional environment, the new industry will concentrate at that particular place.

Conclusion

In sum, historical accidents and urbanization economies (e.g. a generic knowledge base) may play a role in the spatial formation of new industries at their initial stage of development. Besides agglomeration economies, we have distinguished three other factors: spin-offs, network relations, and dynamic organizational capabilities. The first two factors can determine the spatial evolution of a new industry because they lead to the transfer of knowledge and successful routines between firms. The third factor can also influence the place of new industries, since firms with superior dynamic capabilities are more capable of solving internal problems when confronted with change. In principle, these three factors are of a non-spatial nature. In reality, geography might play a role: spin-offs locate near their parent organizations, network relations are facilitated by geographical proximity, and local firms may more easily monitor and imitate successful dynamic organizational capabilities of other local firms. However, space is not necessarily involved, and its impact can only be demonstrated through empirical work.

Summarizing, we can formulate the following expectations that will guide the empirical analysis presented in this paper: (1) firms do not benefit from localisation economies, but might benefit form urbanisation economies, (2) spin-offs perform better since they have more experience in the sector (3), firms with network relations (or a high degree of connectivity) perform better, and (4) firms with dynamic organizational routines perform better because they can deal with rapid change.

3. Data

To test the hypotheses formulated in the previous section, 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 and the second, extended, survey between June and July 2003.

The aim of the first survey was selecting the research population, because the firm activity software development is not distinguished in a specific NACE code. We have selected at random half of all firms with two or more fulltime employees[1] registered at NACE

[1] The large number of 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 very small firms are often part-time activities of persons who also work at other firms or firms that never started their activities (see Bleichrodt et al 1992).

codes 72101, 72102, 7220 and 7230[2] at the Chamber of Commerce. Firms that are specialised in software development are most likely to be registered at one of these NACE codes. The selected 4144 firms have all been approached by telephone. A large number of these firms were not eligible, because firms quitted their activities or were not specialised in ICT. Finally, we have gathered the reactions of 1608 ICT firms specialised in diverse activities such as software development, computer and Internet services, and industrial automation. The research population of this empirical study has been restricted to the 617 firms (34.8%) that mentioned to develop their own software with the aim to sell the product direct on the market. Firms that develop embedded software, that is software only sold included in hardware, are excluded from the research population since their main activity is electronic engineering and not software development.

This paper draws on the data collected in the second, more extended, survey conducted among the 617 software developers that have been selected in the first survey. These entrepreneurs have been interviewed on the innovative behaviour of the firm, the background of the founder, network relations, dynamic capabilities and several firm characteristics. The response rate was 43%, i.e. 265 firms and is representative for the total research population with respect to firm size, registration at NACE codes and the location of the firms within the Netherlands.

Although the software sector can be divided in several sub-sectors, the Dutch software sector, and therefore our research population, is dominated by so-called *enterprise* software firms. These firms develop software platforms or modules that are extensively customised for individual clients (Casper *et al*. 2004). The sub-sector includes those firms developing enterprise resource planning (ERP), customer relationship management (CRM), groupware and systems integration as well as firms creating 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. Most firms are specialised in small niche markets, for example dentists, insurance companies, travel agencies etc. and 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 although they are specialised in a wide diversity of niche markets.

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[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 systems 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.

All firm level variables including the dependent variable are composed with the reactions of the entrepreneurs on questions in the second survey. However, to construct variables on the regional level, i.e. to measure the effect of agglomeration economies, we have used another dataset, the National Information System on Employment (LISA) of 2001. This dataset consists of employment in all sectors in the Netherlands and provides these data on the firm level. From this data, we have selected the total employment and employment in NACE code 72 and aggregated those data to the COROP-level to test for the effects of specialisation and total employment per region. The division in COROP regions has been developed in the 1970s and consist of functional regions that indicate a regional labour market. The Netherlands is divided into 40 COROP-regions. 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 selected the innovative productivity of firms. We have decided to focus on the innovative behaviour of the firms to be able to measure the effect of agglomeration economies and network relations. Both factors are assumed to facilitate knowledge spillovers that most likely contribute to the innovative behaviour or technological capability of the firm. Firms that benefit from knowledge spillovers not necessarily have a higher total turnover. Therefore, to be able to test to potential effect of these factors on the firm's performance, innovative behaviour is a better proxy.

The main advantage of innovation productivity as an indicator for the innovative behaviour of firms is that it indicates how capable firms are in managing their R&D (Klepper & Simons 2000). This indicator provides insight in the efficiency of the organisational routines and competences of the firms. Compared to other often-used proxies for innovation within firms, innovation productivity has several advantages. 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. The main disadvantage of patents is that, especially in the software sector, most innovations are not protected by patents and, consequently, patents might underestimate the innovative behaviour of these firms. A more recently used indicator is the innovation output of firms, i.e. the percentage of turnover due to sales of new products. However, this measure is often used to determine which factors contribute to the innovative behaviour of the firm. In these studies, innovation input is one of the explanatory variables.

Since the aim of this study does not require including innovation input in the model and efficiency gives more information on the innovative behaviour, the innovative productivity is selected as indicator.

The innovative productivity of the firms has been developed with 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 helped to develop the new product and what percentage of the total turnover during the last year was due to the sales of the new product. Firms younger than 3 years are excluded to avoid a bias (46 firms). The new product of these firms is often their first product and, consequently, the innovation input and output will be 100%. Of all firms older than 3 years, 34 firms answered that they have not developed a new product since 2000 and 8 firms reported that they are still working on a new product. These firms are also excluded from the dataset. Another 8 firms have not answered one of the questions on innovation input or output. Therefore, the total number of firms included in this empirical analysis is 169.

Our empirical analysis seems to have to deal with a multilevel problem, because potentially relevant factors are measured on two levels of analysis. Data on the background of the founder, relations with other firms, dynamic capabilities and firm size, age and type of innovation are all measured on the firm level. The other level is the regional level on which agglomeration economies play a role. Many studies treat such data by using individuals as the basic unit of analysis and linking 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; erroneous conclusions may be drawn about their impact on the dependent variable (Snijders & Bosker 1999). Therefore, we have tested whether the –2 log likelihood of an Ordinary Least Squares (OLS) regression is significantly higher than that of a random intercept-only model. However, the difference between the two models was only 1, which implies that the differences between regions are not statistically significant. In other words, a multilevel analysis is not necessary.

However, an OLS regression model is still not appropriate since the innovative productivity of firms cannot take a value below zero. 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 & 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).

The hypotheses formulated in section 2 have been tested with five tobit models. To measure the effect of each factor, several independent variables are included as indicators for that factor in the model. When an explanatory variable has a significant or almost significant effect, 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 innovation the firm has developed, the number of fulltime employees, and the age of the firm. The first variable measures the strategy the firm has used to innovate. Has the firm developed a product radically different from the previous products or adapted existing products incrementally? This is a dummy coded variable and a value of 1 equals the production of radically different products. The other two firm characteristics are the number of fulltime employees in the firm (size) and the number of years that the firm exists (age). All models tested negative for multicollinearity (see appendix 1).

5. Empirical results

This section of the paper describes our empirical analysis of the effect 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 agglomeration economies. In the second, third and fourth model, we include respectively the effect of network relations, background of the founder and dynamic capabilities. The fifth and final model also includes three moderating effects, which clearly improve the model. During the discussion of the results, we will mention which independent variables have been developed to measure the four factors. Table 1 gives the descriptive statistics for the used variables.

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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 an indicator of unexplained variance.

Agglomeration economies

First, we deal with the effect of regional differences on the innovative productivity of the Dutch software firms. The first hypothesis we have tested states that *firms do not benefit from localisation economies, but might benefit from urbanisation economies*. 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 development platforms, from a few multinationals. High-educated and skilled employees are the main input of these firms. Therefore, we have decided to focus on the specialisation of the labour market to test the effect of localisation economies.

The independent variable we use to determine the specialisation of the local labour market is a location quotient of the 2001 share of total employment in a region accounted for by the employment in the ICT sector in that region, divided by the share of employment in the Netherlands accounted by the ICT sector. This index is similar to the one used by Glaeser et al (1992). This index is measured on the COROP level. Each individual firm gets the score assigned to the region where it is located.

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

	Mean	Std. Dev.	Minimum	Maximum	N
1. log innovative productivity	1.76	0.60	0	2.70	169
2. IT specialisation region	1.13	0.71	0.16	2.74	169
3. log total employment region	5.33	0.33	4.53	5.84	169
4. log customers within 50 km	1.36	0.50	0	2.00	167
5. Strong relation customers	0.63	0.48	0	1.00	169
6. Regular contact competitors	0.63	0.48	0	1.00	169
7. Spin-off	0.31	0.46	0	1.00	169
8. Experience in the ICT sector	0.21	0.41	0	1.00	169
9. Problems with customers	0.49	0.50	0	1.00	168
10. Problems new employees	0.54	0.50	0	1.00	163
11. Type of innovation	0.26	0.44	0	1.00	169
12. Fulltime employment	13.49	17.00	2.00	100.00	169
13. Firm age	10.78	5.84	3.00	28.00	169

To test the potential effect of urbanisation economies, two independent variables are included in the model. The first indicator is the total employment per COROP region. The second variable indicates whether the firm is located in a region that offers a beneficial market situation for the individual firm. In the survey, entrepreneurs have been asked which percentage of the total number of their customers is located within a radius of 50 kilometres surrounding their firm. An advantage of this indicator is that it is not restricted by administrative boundaries.

In model 1, we have tested the effect of these three independent variables on the innovation productivity of the software firms and included the three control variables (see table 1). Contrary to our expectation, localisation economies have a significant and positive effect, while both indicators for urbanisation economies are insignificant. In other words, firms located in a region with a relatively high percentage of ICT employment have a higher innovative productivity. This positive effect is caused by a negative correlation between the degree of ICT specialisation of the region and the percentage of employees that developed the new product, i.e. the innovation input ($p = 0.00$ and correlation = -0.26). Software firms located in concentration areas are more efficient in their use of innovation inputs. The correlation between a location within a region with a relatively high percentage of ICT employment and the innovation output (percentage of turnover due to sales of new products) has a negative sign. However, this indicator is not significant ($p = 0.125$).

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 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, these findings might be caused by the characteristics of the dependent variable. Firms that introduce a more radical innovation or a more complex product might have a lower innovative productivity. The development of a radical and complex new product takes a lot of time and customers might be more reluctant to accept it, which might cause an initially low percentage of the output due to the sales of that new product. Firm age has a significant and negative effect on the innovation productivity of firms. In other words, firms that are younger perform better. The effect of firm size is not significant.

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	3.127*** (0.899)	1.855 *** (0.238)	1.854*** (0.226)	1.800*** (0.235)	2.029*** (0.235)
IT specialization region	0.189** (0.0779)	0.122* (0.066)	0.124* (0.066)	0.135** (0.066)	0.002 (0.092)
Log total employment per region	-0.240 (0.168)				
Log percentage of customers within 50 km	-0.042 (0.095)				
Network relation customers		0.066 (0.096)			
Relation with competitors		0.025 (0.096)			
Spin-off			0.174 (0.106)	0.186* (0.103)	-0.026 (0.116)
Experience in the ICT sector			-0.034 (0.122)		
Problems finding customers				-0.159* (0.095)	-0.007 (0.106)
Problems getting new employees				0.146 (0.095)	-0.204 (0.173)
Spin-off * type of innovation					0.675*** (0.221)
IT specialization region * problems finding employees					0.318** (0.129)
Problems with customers * type of innovation					-0.534** (0.212)
Radical innovation	-0.400*** (0.107)	-0.410*** (0.107)	-0.415*** (0.106)	-0.399*** (0.108)	-0.362** (0.164)
Log fulltime employment	0.173 (0.121)	0.161 (0.119)	0.154 (0.118)	0.189 (0.125)	0.156 (0.119)
Log firm age	-0.392* (0.206)	-0.360* (0.203)	-0.340* (0.203)	-0.356* (0.205)	-0.411** (0.199)
Number of observations	*167*	*169*	*169*	*162*	*162*
Log likelihood	*-158.49*	*-160.57*	*-159.10*	*-152.33*	*-143.54*
-2 log likelihood	*319.83*	*322.92*	*319.84*	*306.56***	*288.7****
Sigma	*0.60****	*0.60****	*0.59****	*0.59****	*0.56****
Pseudo R^2	*0.135*	*0.133*	*0.148*	*0.182*	*0.291*

[a] Dependent variable: Log10 (innovative productivity + 1)
* $p < 0.10$; ** $p < 0.05$; *** $p < 0.01$

Network relations

In model 2, we test the second hypothesis that *software firms involved in network relations perform better.* The demands of customers are the main incentive for new product development. In our survey, about 70% of all innovative firms indicated that their 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 (see Grabher 2002). Software development requires detailed specification of the characteristics of the product to integrate the two products. Regular contacts with other software firms might be beneficial. Therefore, we assume that firms involved in network relations with customers and competitors perform better.

We have not included variables to indicate the relation with suppliers and universities, because our survey showed that these relations are standardized or 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 they easily order the necessary supply at the Dutch sales department of multinationals such as Microsoft, IBM etc. or even on the Internet. The high level of standardisation of these supplies makes this possible.

To test the importance of network relations, 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 relation 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 the product to adapt it to their needs. All other firms have a pure market relationship with their customers. The other independent variable is also a 1-0 dummy variable that indicates whether the software firm has regular contacts with other software firms and 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 relation. However, both variables are not correlated which implies that firms involved in strong relations with customers not necessarily have regular contacts with customers (see appendix 1).

In model 2, we have added the two variables for the network relations. Contrary to our assumption, both variables have no significant effect on the innovation productivity of the firms (see table 2). The coefficient of specialisation of the labour market remains positive and significant.

Background of the founder

Third, the pre-entry background of entrants might affect the performance of software firms. Our third assumption states *spin-offs have a higher innovative productivity since they have more experience in the sector*.

To be able to test the effect of the background of the founder, entrepreneurs have been asked whether the founder(s) of the firm had working experience and, if they had, what the main activity was of their previous employer. Using these answers, two dummy coded variables have been developed. The first variable is spin-off and a value of 1 equals that at least one of the founders use to work in the software sector. To account for the possible 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 is included. A value of 1 equals one of the founders having 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 and 21% of all founders used to work at another ICT firm.

These two dummy-coded independent variables are added in model 3. Again we have to reject our assumption. Both variables do not have a significant effect on the innovation productivity of firms compared to other start-ups (see table 2). The variable for working experience in the ICT sector certainly not contributes to the model (p = 0.78). However, the variable spin-off is almost significant (p = 0.10) and improves the model. This variable indeed has a positive effect on the performance of the software firms. Therefore, we include this variable in the model.

Dynamic organisational capabilities

The software sector is still a relatively young sector. As table 1 shows, the average age of the interviewed firms is just over than 10 years. Our assumption is, therefore, that *software firms with dynamic organisational capabilities perform better since they can deal with the many changes that still occur in the sector*. 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).

However, the Dutch software sector 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. Most firms attempted to attract new employees to meet the quickly rising demands, and a shortage in ICT employment appeared. This situation completely changed after the year 2000. At the moment, many customers postpone their investments in new software packages due to the drop in economic growth and the burst of the Internet bubble. The demand for software has dropped dramatically.

Therefore, we have decided to measure the dynamic capabilities of the firms with respect to their market situation. 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 has developed a strategy to deal with these problems to determine the urgency of the problem. We have constructed two 1-0 variables to measure the effect of the dynamic capabilities. The first variable indicates whether the firm has problems getting customers and a value of 1 confirms that the firm has those problems and uses a strategy to overcome those problems. The other variable indicates the problems and strategy to find new employees. Again a value of 1 equals having those problems. From table 1, we can see that 49% of all firms had problems with getting customers and 54% of the firms with finding new employees.

In the fourth model, these two variables are added. Having problems finding new employees has no significant effect ($p = 0.13$), while the effect of having problems with finding new customers has a significant and negative effect (see table 2). The firms that are incapable of dealing with the drop in demand are performing worse. Their product does not match the demand for software, which is confirmed by a negative correlation between having problems finding new customers and the percentage of turnover due to sales of the new product ($p = 0.087$).

Moderating effects

In model 5, we have tested whether certain 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.

The first moderating effect is that having working experience in the software sector positively affects the relation between developing a radical innovation and the innovative productivity. As said before, the innovation strategy of introducing a radically different product has a negative effect on the innovative productivity of software firms. However, this negative effect disappears when a more experienced entrepreneur (spin-off) has founded the firm. Those entrepreneurs can develop a radically new product and still have a good balance between the innovation output and innovation input. Possibly, these entrepreneurs have a better insight in the market demand or how to organise the development of a radically new product due to their working experience. 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 the 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. 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 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 the innovative productivity. 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 ($p = 0.047$ and Pearson correlation = -0.136). 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.

6. Discussion and conclusion

The aim of this paper was to test whether agglomeration economies indeed stimulate the performance of software firms or if this effect is actually caused by the involvement in network relations, the experience of the founder or the organisational capabilities of the firm. However, our empirical study shows that in fact localisation economies and two of the three other factors affect the innovative productivity of Dutch software simultaneously. The main 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 relations do not seem to affect the performance of firms.

Moreover, our findings for the effect of localisation economies are in line with an interesting debate on 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 have significantly less fulltime employment developing the new product (i.e., a lower innovation input). The correlation between this factor 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 spill-overs between them and the other firms located in that region? Or are they forced to use fewer employees due to stronger competition for ICT employment in these areas? The interaction term in model 5 showed that this effect is restricted to firms that have problems finding new employees, suggesting that stronger competition explains this outcome.

Sorensen (2003) also discusses whether the spatial concentration of firms is indeed beneficial. According to him, the importance of agglomeration economies providing benefits to local firms is overestimated. In his empirical studies, he demonstrates that the best performing regions (the ones with the highest founding rates) also show the highest failure rates. The competition within these specialised regions is higher. He explains the spatial concentration of firms by social networks. Entrepreneurs primarily arise from existing industries, because they are involved in social networks necessary to recognize new opportunities in the industry and mobilize the required intellectual, financial and human capital. In a similar way, Zhang (2003) has suggested that successful entrepreneurs may act as role models, inspiring new entrepreneurs, leading to the emergence of clusters. In this respect, he proposes a real Schumpeterian explanation in which swarming effects occur: “the appearance of one or a few entrepreneurs facilitates the appearance of others, and those the appearance of more, in ever-increasing numbers” (p. 534). In other words, imitation behaviour might explain the spatial concentration of industries and not the benefits of such agglomerations.

Note that both studies suggest that spin-offs play an important role in determining the spatial pattern of an industry. Spin-offs are assumed to develop mainly in regions where the industry is concentrated since these firms typically locate near their parent and, consequently, spin-off dynamics further strengthen the existing spatial pattern. Our empirical study indeed shows that spin-offs have a higher innovative productivity especially when these firms develop more radical innovations. However, we do not find any evidence that these more experienced firms are mainly located in the concentration regions (see appendix 1). Only the firms with founders that have experience in the ICT sector excluding the software firms are significantly more often located in the more specialised regions.

Future empirical work should focus on disentangling the role of agglomeration economies and spin-off dynamics in the spatial evolution of new industries. Moreover, our empirical study has shown that besides agglomeration economies other factors affect the performance of firms. As discussed in section 2, these factors might have (indirect) implications for the spatial evolution of an industry. The potential geographical implications of these factors should be further explored empirically in order to get a better understanding of the spatial evolution of industries.

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Appendix 1. Descriptive statistics

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

	1	2	3	4	5	6	7	8	9	10	11	12
1. log innovative productivity												
2. IT specialisation region	0.17**											
3. log total employment region	0.02	0.55***										
4. log customers within 50 km	-0.04	0.07	0.07									
5. Strong relation customers	0.03	-0.08	-0.06	0.08								
6. Regular contact competitors	0.04	0.05	-0.01	0.22***	0.01							
7. Spin-off	0.13**	-0.02	-0.14**	0.04	-0.05	0.00						
8. Experience in the ICT sector	-0.04	0.14**	0.13**	0.04	0.03	0.03	-0.34***					
9. Problems with customers	-0.11*	0.01	-0.07	0.08	-0.07	0.16**	0.09	0.06				
10. Problems new employees	0.16**	-0.03	-0.01	0.03	0.02	0.11*	0.02	0.02	-0.04			
11. Type of innovation	-0.31***	-0.09	-0.04	0.05	0.06	-0.02	0.04	0.03	0.04	-0.12*		
12. Log fulltime employment	0.14**	0.14**	0.08	-0.15**	-0.01	0.06	0.02	-0.02	0.13**	0.15**	-0.14**	
13. Log firm age	-0.12*	0.06	-0.06	-0.10	-0.06	-0.03	-0.09	-0.07	-0.02	0.01	0.03	0.21***

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