INNOVATION DYNAMICS IN SPACE: LOCAL ACTORS AND LOCAL FACTORS

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Abstract
This paper addresses the issue of technogenesis and its geographical pattern. It aims to offer both a general analysis framework and a test on innovation data from several European cities. This framework is mainly built on the product life-cycle and the incubation approach. On the basis of this framework, it is argued that the phases of an industrial life-cycle have several firm-specific effects. First, these phases influence innovativeness and thus profit levels, output and employment of firms in a spatially distinct way. Second, the phases of the life-cycle mirror the importance of local factors for innovations, and third, they affect strategic decisions of firms, inter alia by influencing the source of the competitive edge. Furthermore, this paper also aims to model effects of relevant local factors on innovativeness by means of logit analysis, subsequent to a qualitative impact approach based on the recently developed rough set analysis. Our empirical results from various European cities show that the successive phases of the industrial life-cycle tend to create spatially recognizable impacts on innovativeness of firms. Accordingly, the evolution of the importance of local factors for innovations is also found to reflect a distinct time path. Among more than 20 local factors, the interviewed firms appear to consider support measures for skills training particularly important for innovations. Accordingly, the results of our logit models reveal that in particular skills training links with a local university contribute significantly to the propensity to innovate.

Keywords: innovativeness, life-cycle, incubation, logit model, rough set analysis

1. Introduction

The literature on technological innovation, technogenesis and its spatial dynamics is vast and covers a wide range of both theoretical and applied studies. For overviews we refer here inter alia to Bertuglia, Lombardo and Nijkamp (1997), Boschma (1994), Cappellin and Nijkamp (1989), Freeman (1987), and Kleinknecht (1987). An often observed phenomenon is that major scientific and/or industrial breakthroughs are discontinuous in nature. Once emerged, such radical transformations tend to produce a rise in new firms or even new industries (see e.g. Suarez-Villa, 1989). In this context, Malecki (1991) distinguishes four long-run Kondratieff waves in the past centuries. In his view, the last technological revolution or wave commences already in the late 1940s; it is closely linked to a micro-electronics cluster of innovative industries. Although major inventions in the micro-electronics sector have also affected products of other industries, it may be argued that the effects on other industries are mainly of a process nature. For example, automation of production processes in the traditional metal industry may have increased productivity, but this does not, ipso facto, represent a major technological revolution in the sector itself. Consequently, it may be argued that the metal industry, which according to Boschma (1994) exhibited major breakthroughs in the early stages of the industrial revolution, is now living in a more mature and later phase of its life-cycle than the micro-electronics industry (see e.g. Markusen, 1987).

The present study analyses the spatial-economic aspects of industrial age differences in spatial innovation dynamics. In our approach we will focus in particular on the life-cycle and the incubation approach. On the basis of these two paradigms, we will design a conceptual model, which will serve as an analytical framework for formulating a series of hypotheses which may be subsequently tested in our empirical work on innovation generation and diffusion in European cities. In so doing, special attention is paid to the role of local characteristics in innovative behaviour.

This paper is organized as follows. It will first offer a conceptual model for innovation dynamics in space, which will serve as an analysis framework to derive several testable hypotheses. Second, the paper aims to test these hypotheses in an exploratory way. Third, an explanatory analysis is carried out. The statistical models used are based on a logit approach and a rough set approach. The data used are derived from the so-called URBINNO network and cover cities from three European countries (Great-Britain, Italy and The Netherlands). Finally, some concluding comments will finish the paper.

2. A Concise Overview of the Life-Cycle and the Incubation Approach

In the standard approach on the analysis of technological change, the innovation model has essentially three stages: (i) basic research produces a scientific or technological discovery; (ii) creative firms develop this invention towards a new product; (iii) and exisiting firms apply this product for commercial use. Through market reactions, successful commercial use has feedback effects on scientific basic research as well as on R&D efforts of firms (see e.g. Kline and Rosenberg, 1987). Davelaar (1991) argues that such a change in science and technology leads to major inventions and basic innovations which, together with socio-institutional and economic forces, form a new technological system whose occurrence is discontinuous in time. Dosi (1988) explains the importance of basic research in that the progress in scientific knowledge widens the pool of potential technological paradigms (or technological systems) from which only a small set of paradigms is actually developed. New technological systems, which happen to emerge, give birth to new technological trajectories or sequences of innovations, along which a swarming process of (new Schumpeterian) firms produces further product and process innovations with a decreasing marginal product. A good example of such a technological regime (or system) is the micro-electronics industry which has been built up around such major innovations as the transistor (Boschma, 1994). These swarming processes along technological trajectories form life-cycles for technologies and industries[1]. When adjustments and innovations within existing systems become rare and marginal, new technological systems or regimes will eventually replace the old ones.

A swarming process along technological trajectories can be subdivided into three successive phases, which Davelaar (1991) coins <u>incubation</u>, <u>competition</u> and <u>stagnation</u> (see also Markusen, 1987). These phases will now concisely be discussed. During the <u>incubation</u> phase, firms which are either new or incumbent, produce numerous early (and often significant) innovations, which are mostly product innovations and which are encouraged by the technological push of a scientific basic invention. Products are then not yet standardized, which means that the uncertainty concerning market reactions is high. Innovations during this phase put specific demands on the surrounding business environment. Information concerning unstandardized products, market reactions and skills on the labour market in terms of producing and developing these new products are important conditions for a successful innovation.

During the <u>competition</u> phase, new product innovations tend to become more marginal, while process innovations tend to become more wide spread. Product innovations lose thus importance over time, as product innovations cannot be created endlessly within one technological system. Process innovations will then gradually take over, because when further product innovations are increasingly hard to create and when products become more standardized, firms try to develop better production processes to ensure or enhance their competitiveness. A continuous improvement of competitiveness is needed because of an increasing number of new firms entering a potentially promising market.

[1] In essence, this approach is closely related to the well-known spatial product-life cycle approach developed by Vernon (1966).

Finally, during the stagnation phase, products and services are reaching a state of market saturation. Consequently, because additional innovations (both product innovations and later on also process innovations) are becoming rare and markets tend to become saturated, price competition will take over, which leads to a decrease in the number of firms, and eventually to a situation of oligopolistic competition.

It ought to be recognized that innovation is a spatial-dynamic process. Initial locations of new technological systems are often somewhat arbitrary (see Krugman, 1991). According to Markusen (1987), the initial stage of a technological trajectory is concentrated in a very few locations. Although not all new production sectors settle at the place of major inventions, in principle firms tend to agglomerate near innovating firms, mainly because of the need for skilled labour and information. Davelaar (1991) argues that during the incubation phase, when major product innovations are made, the swarming process of (new Schumpeterian) firms is concentrated in central (usually urban) areas, because early innovations are more dependent on the urban 'milieu' than subsequent innovations.

As argued above, possibilities to significantly improve existing products decrease during the competition phase: product innovations become more marginal and process innovations take over. These later innovations do not demand so much from the urban production milieu as innovations in earlier stages of a technological trajectory, because further improvements are concentrated on existing products (which have been proven to be the most successful) and also on production processes of these goods. Therefore, the presence of a basic research institution is not of crucial importance anymore during this phase. Furthermore, in the mean time there has also been ample opportunity for non-central areas to develop adequate innovation infrastructure to meet new demands. Thus, innovativeness of entrepreneurs in intermediate and peripherial areas will then tend to rise. Besides, markets in central areas are reaching saturation, and hence households and firms in other areas will take the lead in the adoption of new technologies; some production plants may even leave the central areas and concentrate on growing markets elsewhere. In other words, during the competition phase both supply and demand conditions contribute to a shift in innovation activity to non-central areas.

During the stagnation phase of innovative behaviour, peripheral (often rural) areas may even be in a favourable position. The relatively low number of innovations and the standardization of the products reduce the importance of local factors even further, while price competition as the source of competitiveness may then favour peripheral areas where factor prices may be expected to be lower than in central areas.

3. A Test Framework for Space-Time Innovation Patterns

3.1 Spatio-temporal patterns of innovations

On the basis of the previous reflections we will now develop a conceptual space-time analysis framework, which may lend itself for empirical testing. The evolution of the relative innovative performance over time in central, intermediate and peripheral areas is depicted in Figures 1-3, which map out a slightly elaborated version of Davelaar's model of ideal-typical innovative performance of central areas in the course of time relative to the average innovative performance of firms in other areas (Davelaar, 1991). During the incubation phase, central areas perform an above average product and process innovativeness (Figure 1). Over time, the central areas become less and less innovative relative to the others, because intermediate and peripherial areas take over for the reasons discussed above. The process innovativeness in central areas is lower than the product innovativeness, particularly after the incubation phase, because process innovations are realized more frequently during later phases and are therefore more concentrated in non-central areas.

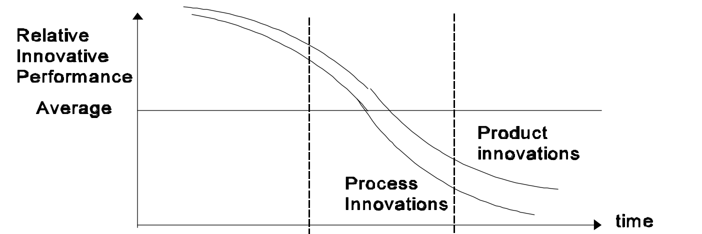

Figure 1. Evolution of Relative Innovation Performance in Central Areas.
Source: Davelaar (1991).

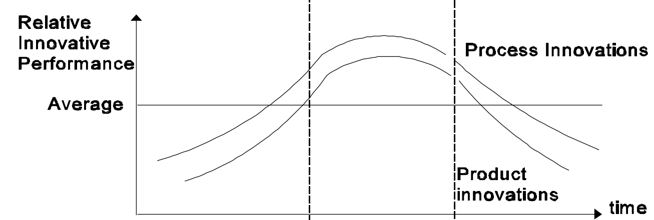

Figure 2. Evolution of Relative Innovation Performance in Intermediate Areas.

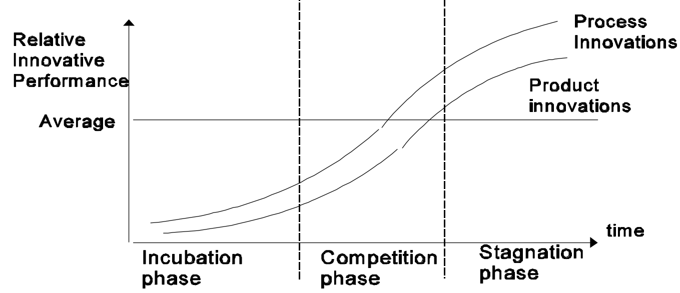

Figure 3. Evolution of Relative Innovation Performance in Peripheral Areas.

The above description can easily be extended to cover also non-central (i.e. intermediate and peripheral) areas. Figures 2 and 3 suggest that the relative innovative performance in the intermediate and peripheral areas is over time more or less opposite to that in the central areas. Innovative performance is upward sloping and both types of areas perform a higher process than product innovativeness. The difference between the intermediate and peripheral areas is that the innovative performance in peripheral areas tends to reach the average level at a later stage than that in intermediate areas.

A proper way of studying the conceptual model depicted in Figures 1-3 would be to analyse time series. However, time series at the micro level of the firm are very rare (see e.g. Harrison et al., 1996 and Tervo and Niittykangas, 1994). Therefore, we will resort here to a simplified comparative static approach: we will take one point in time and check whether or not our empirical results are in accordance with the space-time implications of our conceptual model. Figures 4-6 show the relative performance of the three different types of areas (central, intermediate and peripheral) concerning product and process innovations in the incubation, competition and stagnation phases. These figures are derived directly from Figures 1-3. They describe the same phenomenon, but only from a different point of view: each of the Figures 1-3 has the three phases of a life-cycle, but concerns only one specific type of area, while each of the Figures 4-6 has all three types of areas, but contains only one phase of the life-cycle.

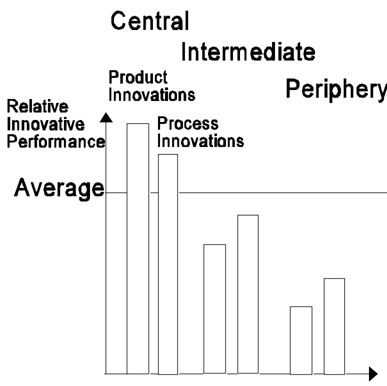

Figure 4. Relative Innovative Performance in the Incubation Phase

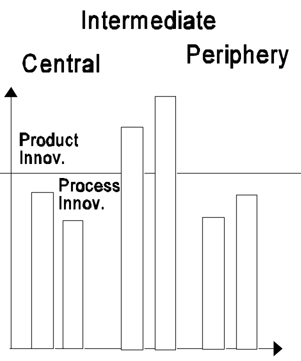

Figure 5. Relative Innovative Performance in the Competition Phase

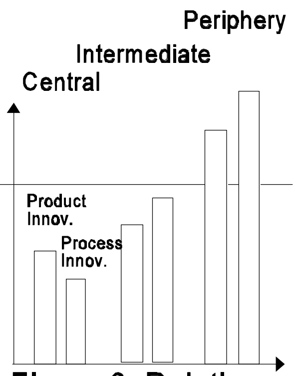

Figure 6. Relative Innovative Performance in the Stagnation Phase

The conceptual model - now redrawn in Figures 4-6 - has two major implications. The first one concerns the link between the innovative performance of firms and their position in a space-time frame: (a) when the share of innovating firms decreases with increasing peripherality, the industry concerned is likely living in the incubation phase of the life-cycle; (b) similarly, if firms in intermediate areas are more innovative than firms in central and peripheral areas, then the industry at hand is most probably living in the competition phase; (c) and finally, if firms in peripheral areas have the highest innovation rate, then the industry concerned is likely living in the stagnation phase of its life-cycle. A second implication concerns relative product and process innovativeness in the three types of areas: regardless of the phase of the life-cycle, central areas tend to perform better in terms of product than process innovations relative to other areas; intermediate and peripheral areas tend to show a reverse pattern, because process innovations are realized more frequently during later phases when innovative behaviour is more concentrated in non-central areas.

After the exposition of the basic conceptual framework, two relevant hypotheses to be tested in the sequel, are derived from the above reasoning. Our first hypothesis is:
H_1: *an industry produces more innovations in earlier phases of its life-cycle.*

A second, related hypothesis is:
H_2: *the phase of the life-cycle of an industry can be identified on the basis of the relative innovativeness of firms in distinct relevant area categories.*

If an empirical investigation of a given industry were able to produce a pattern similar to the one depicted in Figures 4-6, one might plausibly argue that the specific industry is living in one of the (incubation, competition or stagnation) phases of its life-cycle. In addition, we may plausibly argue that the phase of the life-cycle can also be identified on the basis of the competitive edge of firms in the industry at hand. This will be the subject matter of the next section.

3.2 The technological life-cycle and the competitive edge of firms

Innovation is not a gradual process taking place in isolation. It may be influenced by strong competition in various stages of life-cycles. The three above mentioned phases of the innovation life-cycle can also be termed as state, market and hierarchy, respectively (see Gordon, 1991). According to Gordon the "framework of political relations" promoted the earliest innovation possibilities, for instance, in microelectronics in the postwar era. Gradually, the path of technical development in this sector became more market-oriented and hence more predictable, which decreased the importance of supportive political relationships, while the importance of market linkages took over, which promoted an increase in the number of new firms. Finally, rising requirements for investments and an uncertain development of demand shifted the market-based innovation system towards vertical integration in the electronics industry after the mid-1970s.

Studies of Bramatti and Senn (1991) and Markusen (1987) show various common elements to this line of thinking. According to Bramatti and Senn, firms tend to face three stages of the strategic life-cycle. First, when a firm introduces a new product, it concentrates on the production space of its activities. Subsequently, when other firms producing the same specific product enter the market, the focus will change to the market space in addition to the production space. With competition becoming more and more fierce, additional attention is paid to the support space. During this phase, vertical (seller-buyer) and horizontal (between competitors and between complementary firms) integration and cooperation will take place with various intensities. In other words, it can be argued that the strategic competitive edge of firms within an area tends to exhibit a life-cycle. This life-cycle would start with product innovativeness as the competitive edge, followed by marketing and ending with a strategic alliance type of behaviour. In this vein, we may formulate another two hypotheses, both related to the firm's competitive edge and the phases of the life-cycle.

A third hypothesis, which resembles the first one, is:
H_3: *product innovations serve more commonly as a competitive edge in the (more innovative) younger industries than in older ones.*

The product life-cycle and strategic life-cycle approaches together yield a fourth, related hypothesis which resembles the second one:
H_4: *the phase of the life-cycle of an industry can be identified on the basis of how broadly the product innovativeness serves as a competitive edge of firms in distinct area categories.*

Before testing these hypotheses, we will first concentrate more carefully on the specific local factors and propose three additional hypotheses that may test the importance of the local 'milieu' for innovations.

3.3 Innovativeness as a local process

Intrinsic regional features may affect innovativeness of firms within a given region, in addition to the different engagement of these firms in the development of new technologies and processes. On the one hand, the region's innovative activity is determined by R&D activity, size, market power, industry, and phase of the 'industry-technology' life-cycle of firms located in the region (see Ormrod, 1996 and Love et al., 1996). On the other hand, regional characteristics affect the innovative activity of firms by enhancing or inhibiting the effects of innovative inputs of firms in the region (see also Figure 7 below). Davelaar (1991) coins these as production structure and 'production milieu' components, respectively. An implication is that firms which are located in different regions, but have identical innovative inputs, may have different innovative outputs. According to Camagni (1991), the local (innovative) milieu may enhance innovativeness and thus growth of firms, if it reduces the intrinsic uncertainty of the innovation process concerned.

In his study, Davelaar (1991) distinguishes four groups of local factors which affect local innovativeness: (i) agglomeration economies which include location economies accruing from the presence of the same industry, and urban economies accruing from the presence of different industries; (ii) demography and population structure which refers to local resources of human capital, local customers and size of the local market area; (iii) availability of specialized information and intensive communication networks including also educational institutes; and (iv) social overhead capital which responds faster to new demand for technological systems in central areas than in the periphery and which requires various local institutions and physical infrastructure (see also Davelaar and Nijkamp, 1997).

This role of the so-called ’production milieu’ can also be interpreted in a different way. Advocates of the ’innovative milieu’ school argue that human capital, (mainly) informal linkages between firms in a region and synergy effects from a common cultural, psychological and political background, are extremely important (Camagni, 1991). The importance of local resources of human capital results from the fact that it tends to stimulate local collective learning processes, because labour is more mobile within a region than between regions. Boschma (1994) argues that local education and research facilities contribute to this local accumulation of skills and knowledge, because producers gain when at least part of the costs of job training as well as basic R&D are carried out by such institutions.

Camagni (1991) emphasizes the importance of informal linkages both between firms and within various economic actors such as firms, employees and institutions. Local formal and informal networks between firms, which are essential in the acquisition of the latest technology, will likely lead to lower information gathering costs. Local institutions are important parts of local networks, because they overcome market imperfections which inhibit innovative behaviour. The development of collective knowledge as well as formal and informal linkages between suppliers of labour, capital and institutions contribute to a regional identity and culture, which may result in a desire for cooperation. According to Camagni (1991), common cultural roots are important in the formation of tacit knowledge in order to understand and use complex messages and in the formation of commonly accepted beliefs on new products and technologies.

It is clear that Davelaar focuses more on static local factors, like infrastructure, which reduce transaction costs and produce external economies, whereas Camagni addresses synergy effects, which promote a collective learning process and reduce dynamic uncertainty (see also Gertler, 1996 and Harrison, 1996). These various components of the production milieu can be expected to be more favourable in central areas than in other areas, which means that in the incubation phase, when external factors are important for innovations, innovativeness is relatively high in central areas.

The above reflection on the role of uncertainty in innovative behaviour may produce three other testable hypotheses. Our fifth hypothsesis takes for granted that local factors reduce the uncertainty inherent in any innovation. Because process innovations enhance the use of existing products, the uncertainty is lower here, and thus the role of local factors tends to be smaller. Therefore, a fifth hypothesis is:
H_5: *local factors are more important for product than for process innovations.*

Our sixth hypothesis is more directly than the previous one related to the life-cycle approach:
H_6: *local factors are more important for a (more innovative) younger than for an (less innovative) older industry.*

This hypothesis seems plausible, as a younger industry tends to produce more product innovations than an older one.

It goes without saying that local factors are not equally valuable. Therefore, we will also study more carefully the subset of local factors, which turn out to act often as critical success conditions for entrepreneurial innovations. Such a more detailed analysis will be carried out in order to model the effects of this subset of local factors on innovativeness of firms. Clearly, the reasons for a different innovative performance of distinct types of areas may of course also be related to other factors than the phase position in the life-cycle alone. As discussed above, regional innovativeness is determined by production structure and 'production milieu' components. The phase of the life-cycle affects regional innovativeness through the production structure component.

The impact of the 'production milieu' in empirical research is not always very significant. Davelaar (1991) argues that after controlling for the industrial structure, there is limited evidence for a positive impact of the urban 'milieu' on innovativeness of firms. This may be further investigated and tested. Therefore, our seventh hypothesis is:
H_7: *the local 'production milieu' has a positive impact on innovativeness of firms in an area.*

The objective of the next sections is to check whether or not our empirical data support the notion of the ideal-typical innovative performance of areas over time, as outlined above.

4. The Data Set on Innovations

The data set used in our empirical work stems from the co-called URBINNO[2] study and has been compiled by extensively interviewing manufacturing companies in the United Kingdom (208 firms), the Netherlands (33) and Italy (32). Interviews were held among firms in different manufacturing industries. For practical reasons, the empirical investigation in our study is mainly concentrated on those industries which have a sufficient number of observations. These are: manufacturing of machinery and equipments (SIC 29); electrical machinery and apparatus (SIC 31); medical precision and optical instruments, watches and clocks (SIC 33); and motor vehicles, trailers and semi-trailers (SIC 34). All the industries included in the data set are presented in Appendix 1. Furthermore, our empirical investigation

[2] The URBINNO group ("Urban Innovation") was a network of researchers in several European countries. The objective of the group was to study innovations in several urban areas from various points of view, viz. population, urban economy, institutions and infrastructure, and from a micro-urban (i.e., firm level) perspective.

is also dealing with two other, aggregate sectors in order to have a sufficient data base, viz. textile, wearing and leather industries (SIC 17, 18 and 19) together, and basic materials and metal industries (SIC 27 and 28). This seems a plausible approach, because these industries are so close to one another that they will likely benefit from the same source of technological development and hence are likely to live on the same technological trajectory. The urban background of innovative behaviour has been given due attention in the interviews.

The cities in our sample have been subdivided into central, intermediate and peripheral classes on the basis of their size (Table 1). This implies that we expect the spatial diffusion to emerge not only according to physical distance to central regions, but rather according to their ability and willingness to adopt innovations (approximated here by size of a city).

Table 1. Classification of Cities

	Central areas	Intermediate areas	Peripheral areas
Inhabitants	426 000 - 2 000 000	300 000 - 386 000	50 000 - 141 000
Cities	Milano, Rotterdam, Sheffield and Bristol	Eindhoven, Coventry, Newcastle, and Nottingham	Blackburn, Reading, Peterborough, Tilburg and Como
Number of Firms	93	99	81

5. Exploratory Analysis of the Innovation Data

In this section we will present exploratory results from a descriptive analysis of our data set. We have adopted the most straightforward measure of innovativeness (see Harrison et al., 1996); innovativeness of industries in a city is measured by calculating the percentage of firms that has adopted an innovation during the past few years. Table 2 indicates that 39.9 percent of the total of 273 firms mentioned an innovation in this context. At a two-digit level, industry 34 turned out to be the most innovative, as 77.3 percent of the firms in that industry mentioned an innovation. In contrast, in the industries 27-28 together only 29.0 percent mentioned an innovation, while this figure was even down to 21.1 percent for the firms in the industries 17-19. These first exploratory results suggest that the spatial pattern of innovativeness should, according to our conceptual model, be such that for the basic materials and fabricated metal product industries (SIC 27-28) and for textile, wearing and leather industries (SIC 17-19) the most innovative areas would have to be found further in the periphery than for the motor vehicle industry (SIC 34).

The spatially disaggregated results presented in Table 2 appear to mirror this interesting spatial pattern. The manufacturing sector of basic materials and fabricated metal products (except machinery and equipment) (SIC 27 and 28) is likely living in the stagnation phase of its industrial life-cycle: the share of innovating firms tends to rise with increasing peripherality. The manufacturing sector of motor vehicles, trailers and semi-trailers (SIC 34) is likely in the competition phase: the share of innovating firms is the highest in intermediate areas[3]. Sectors concerned with manufacturing of machinery and equipments (29), electrical machinery (31) and medical precision (33) are likely to live also in the competition phase.

Table 2. Percentage of Innovating Firms by Areas and Industry Classes

City class SIC-Industry (N)	All firms	Central areas	Intermediate areas	Peripheral areas	Phase of life cycle
All ind. (273)	39.9%	33.3%	43.4%	43.2%	
17-19 (38)	21.1%				
27-28 (31)	29.0	25.0 [30.0]	27.3 [9.1]	37.5 [50.0]	III [III]
29 (52)	50.0	47.4 [47.4]	58.3 [63.2]	47.6 [35.7]	II [II]
27-29 (83)	42.2	38.7 [35.7]	43.5 [46.2]	44.8 [44.8]	III [II]
31 (30)	56.7	42.9 [33.3]	72.7 [88.9]	50.0 [50.0]	II [II]
33 (19)	52.6	33.3 [33.3]	100.0 [100.0]	50.0 [37.5]	II [II]
34 (22)	77.3	71.4 [55.6]	81.8 [100.0]	75.0 [50.0]	II [II]
30-32 (39)	59.0	50.0 [38.5]	69.2 [80.0]	56.3 [54.5]	II [II]

Note: Numbers in the parentheses denote the number of observations, while numbers in square brackets denote results of the sensitivity analysis (see below).

Table 2 also suggests that overall innovativeness may be higher in intermediate and peripheral areas than in central areas. About 43% of firms in peripheral and intermediate areas mentioned an innovation, whereas about 33% of firms in the central areas did so.

Because by necessity our city classification is somewhat arbitrary, we have performed a sensitivity analysis by reassigning firms to a new city classification, provided that we have approximately an equal number of firms in each areal category. This was done because the industries are not spread equally accross the cities[4]. The above described results tend to be rather similar after re-balancing the city classes (see numbers in square brackets in Table 2). These figures also show some evidence that firms manufacturing basic materials and fabricated metal products (except machinery and equipment), i.e. SIC-industries 27-28, are likely to be found in the stagnation phase of their industrial life-cycle and that firms manufacturing machinery and equipment (SIC 29) as well as industries in the class SIC 30-39 are living in the competition phase. The only change in the new results after the re-balancing

[3] We cannot present spatial results for the industries 17-19 because of the low number of innovative firms in the sample.

[4] In effect, the balancing procedure implies, for instance, that Blackburn was considered as a city belonging to either a peripheral or an intermediate area, and Eindhoven as a city in a central or intermediate area depending on the industry in question.

procedure is that now industries 27-29 tend to live more in the competition phase. In other words, only industries 27-28 and 29 tend to have a different impact on the overall outcome depending on the areal classification.

Our conceptual model implies that, besides the innovative performance of firms, also the source of competitiveness would follow a trajectory in space. The model implies that innovativeness should be the source of competitiveness, particularly in those areas where innovativeness is the highest. In a similar vein, in the more central areas where relative innovativeness has already decreased, marketing and cooperation should serve as competitive edges. We will test now the conceptual model by looking at the question how many firms consider product innovativeness as their competitive edge in the near future.

The results in Table 3 without spatial disaggregation tend to confirm the previous ones. Product innovativeness is more commonly seen as a competitive edge for the firms who have already innovated than for the others who did not. Interestingly, spatially distinct results do not show up to the same extent. Although the results for the industries 27-28 and 29 are in line with the previous ones, the results for industries 30-32 together and for 31 alone turn out to be more ambiguous. The results for the industry classes 34 and 17-19 are different from the previous ones, because these results suggest that the most innovative and the least innovative industry in our sample, would live in the stagnation phase and the incubation of the life-cycle, respectively. The result for the textile, wearing and leather industries implies that new design and innovations in those industries are made in central areas, a result which is certainly supported by the locational pattern of these sectors in the 'Third Italy'.

Table 3. Percentage of Firms With Product Innovations as a Source of Competitive Edge

City class Industry	All cities	Central areas	Intermediate areas	Peripheral areas	Phase of life cycle
All	35.4%	26.9%	42.6%	37.0%	II
17-19	44.7%	100.0	36.4	46.2	I
27-28	12.9	0.0	18.2	25.0	III
29	34.6	31.6	50.0	28.6	II
27-29	26.5	19.4	34.8	27.6	II
31	53.3	57.1	45.5	58.3	(?)
33	47.7	33.3	66.7	20.0	II
34	54.5	42.9	54.5	75.0	III
30-32	48.7	50.0	46.2	50.0	(?)

To summarize the results so far, we conclude that the phase of the industrial life-cycle tends to have implications for the number of innovations in the industry (H_1) and for the innovativeness of regions (H_2). However, the results concerning competitive edges of firms are less unambiguous. Although product innovativeness is more commonly seen as a competitive edge for the firms who have innovated than for the others (H_3), not for all industries a clear spatial pattern could be found (H_4).

The next two hypotheses (H_5 and H_6) on the importance of the local 'milieu' will be tested by means of exploratory background variables derived from Davelaar's (1991) division into four local factors (see Figure 7). The lists of specific local factors under the four headings are examples of factors whose presence may contribute to the innovativeness of firms in the region. The factors distinguished in Figure 7 are the ones included in above mentioned URBINNO questionnaire. Now the importance of local factors for product and process innovations will be tested. Table 4 shows the results for all industries together. The table includes only those 11 local factors which the respondents considered commonly as valuable factors in terms of either product or process innovations.

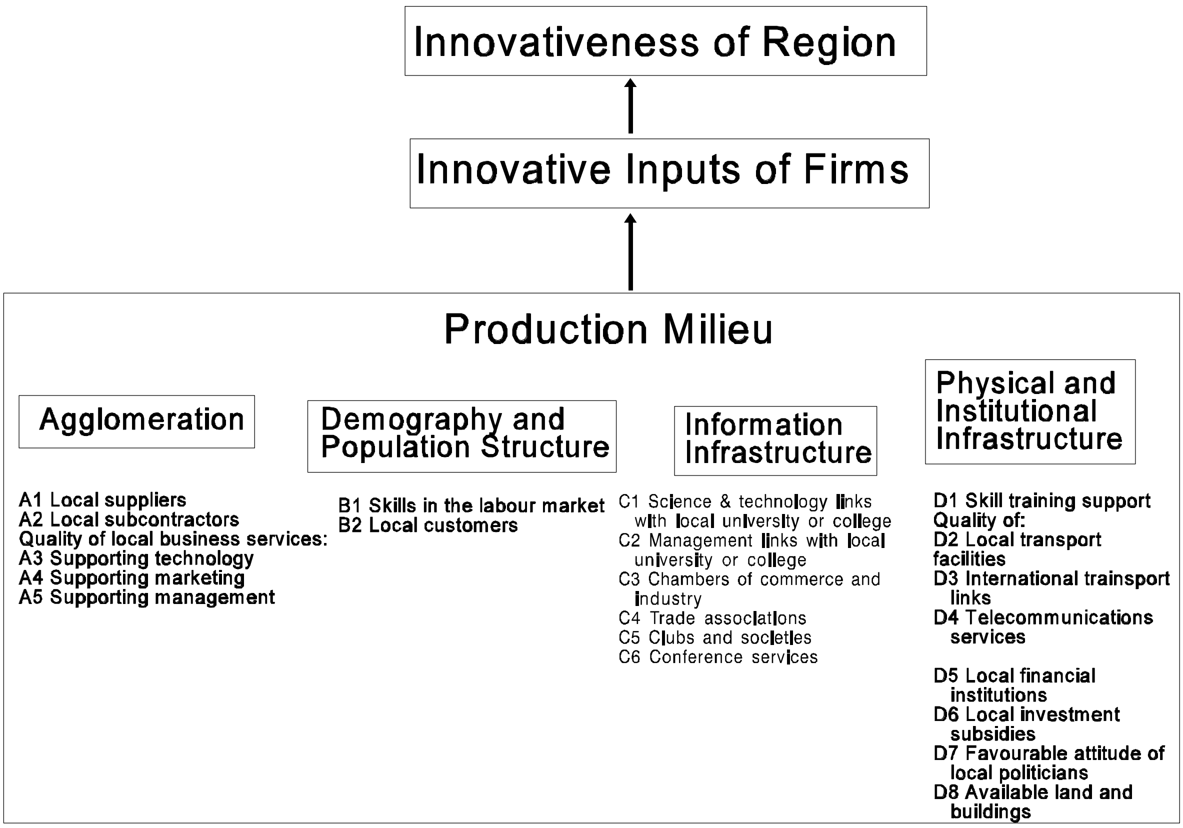

Figure 7. Operational Variables for the Four Groups of Local Factors

According to the firms surveyed, local factors are more important for product than for process innovations. There are only a few exceptions: 'Management links with local universities or colleges' and 'Quality of local business services supporting technology' are more important from the point of view of process innovations than from that of product innovations. Hence, our overall result indicates that the firms in our sample behaved in accordance with our fifth hypothesis (H_5).

The results also indicate that local skills in the labour market (B1), and local skills training support (D1) are the most important local factors. It appears that 48.6 percent of the firms considers skills in the labour market as of 'some importance' or of 'major importance' for product innovations, while 36.1 percent of firms does so for process innovations. The respective numbers concerning training support are 41.4 and 36.1 percent. The quality of telecommunications services (D4), local suppliers (A1) and science and technology links with universities (C1) are the next important factors.

The above results imply that firms can gain benefit by cooperation with a local university, because certain links with the local university would improve those local factors which were mentioned most commonly as important among the firms surveyed (see also Van Geenhuizen and Nijkamp, 1995). For instance, the second important local factor, 'Training links (D1) with local university', supports the most important local factor, i.e. 'Skills in the labour market' (B1); and a nearly as important factor, viz. 'Science and technology links with university' (C1), enhances knowhow. Both factors would be possible candidates to promote innovativeness of firms. The role of university links of firms for innovativeness will be further examined by rough set and logit analysis below in subsections 6.1 and 6.2, respectively.

These results also tend to show that infrastructure is an important factor inducing innovations, as 'Skills training support' and 'Quality of telecommunication services' are among the most important local factors.

Table 4. Percentage of Firms who Consider a Local Factor as Important for Innovations

Local factors	For product innovations	For process innovations	Local factors	For product innov.	For process innov.
Science & technology links with local universities or colleges (C1)	29.7	26.3	Skills in the labour market (B1)	45.9%	36.1%
Management links with local universities or colleges (C2)	20.7	21.1	Skills training support (D1)	41.4	36.1
Quality of local transport facilities (D2)	27.0	18.8	Local suppliers (A1)	32.4	23.3
Quality of international transport links (D3)	27.0	18.8	Local subcontractors (A2)	28.8	19.5
Quality of telecommunications services (D4)	37.8	28.6	Local customers (B2)	27.0	19.5
Quality of local business services supporting technology (A3)	26.1	26.3			

Now, we will focus on our sixth hypothesis. Table 5 presents the results for some selected industries and for firms in distinct areas. The first two columns of these results present the outcomes for highly innovative and low innovative industries (57% of firms in the highly innovating industries mentioned an innovation in contrast to only 18% of firms in the lowly innovating industries). Local factors are clearly more often important for highly innovative than for low innovative industries. The next four columns present the results for the selected industries; the SIC-industries 27-28, which were found to live in the stagnation phase, appear to consider local factors as less valuable than the industries which were found to live in the competition phase (industries 29, 31 and 34). The results clearly show that the local factors are more important for the more innovative (younger) industries than for the less innovative (older) industries. The last three columns show results for the firms in the distinct area categories. The message basically is that local factors are important for more firms in the peripheral and intermediate areas than for firms in central areas. In order to infer this result, we recall that firms in peripheral and intermediate areas innovated clearly more often than those in central areas (see Table 2 above). Therefore, these results indicate that regardless of the classification used (high or low innovative industry, different industries, distinct areas), we can find the pattern that the more firms innovate the more important local factors are. Clearly, these results support our sixth hypothesis (H_6).

Table 5.
Percentage of Firms who Consider a Local Factor as Important for Product Innovations

SIC-industry / Local factors	Innovativeness Low	Innovativeness High	27-28	29	31	34	C.	I.	P.
Skills in the labour market	47.8	50.0	18.5	61.5	35.3	64.7	25.8	51.2	68.6
Skills training support	34.8	44.2	14.8	65.4	29.4	52.8	19.4	48.8	54.3
Local suppliers	30.4	33.7	7.4	46.2	11.8	47.1	16.1	41.9	37.1
Local subcontractors	26.1	30.2	3.7	26.9	29.4	47.1	19.4	39.5	37.1
Local customers	21.7	27.9	11.1	30.8	23.5	35.3	12.9	32.6	25.7
Science & technology links with local university or college	21.7	31.4	7.4	38.5	41.2	29.4	16.1	32.6	37.1
Management links with local university or college	13.0	22.1	0.0	26.9	29.4	23.5	3.2	25.6	28.6
Quality of local transport facilities	30.4	25.6	3.7	42.3	23.5	29.4	6.5	37.2	31.4
Quality of international transport links	39.1	24.4	7.4	38.5	23.5	23.5	3.2	41.9	31.4
Quality of telecommunications services	39.1	37.2	7.4	53.8	35.3	41.2	12.9	46.5	48.6
Quality of local business services supporting technology	13.0	29.1	3.7	38.5	23.5	35.3	6.5	37.2	28.6

Notes: C, I and P. denote respectively central, intermediate and peripheral areas.

Our final exploratory test concerns the seventh hypothesis (H_7). The correlation coefficient between the innovation dummy (whether or not a firm has innovated) and the industrial classification, which subdivides industries into more and less innovative industries, turns out to be 0.39, which is not very high. This means that the presence of highly innovative industries explains only part of the urban innovativeness. Similarly, when firms in the highly and lowly innovating industries are classified according to these city categories, it appears that in the intermediate areas, where firms are most innovative, only 40.4 percent of these firms belong to highly innovating industries (i.e., less than half) and that only 26 percent of firms of the highly innovating industries are located in the intermediate areas (i.e., less than 33.3%). In addition, if we take the three two-digit SIC-industries, which have most observati-ons and within which the firms have innovated most commonly (these are 29, 31 and 34), these firms turn out to be spread among the three city categories, so that peripheral areas have 35, central areas 32, and intermediate areas 26 firms, respectively. In other words, the presence of highly innovating industries does not explain all differences in the innovativeness of the areas, which also leaves some room for other explanatory factors which make firms in one industry more innovative in intermediate areas than in the central or peripheral areas. Therefore, also the production 'milieu' will likely have some effects on the innovativeness of firms, a result which supports our seventh hypothesis (H_7). After this exploratory research we will now offer an explanatory analysis in the next two sections.

6. Explanatory Analysis

6.1 Rough set analysis

Now we will seek some further evidence for the importance of the production milieu for innovativeness of firms (H_7) by applying rough set analysis. Rough set analysis is a fairly recent classification method of an 'if-then' nature (see e.g. Pawlak, 1991; and Slowinski, 1993)[5]. The analysis classifies objects into equivalence classes using available attributes which act as equivalence relationships for the objects considered. Objects in the same equivalence class are indiscernible (indistinguishable). A class which contains only indispensable equivalence relationships (attributes) is called a core. An attribute is indispensable if the classification of the objects becomes less precise when that attribute is left out. The values of the attributes of all objects may be subdivided into condition (background) and decision (response) attributes.

The objective of a rough set analysis is usually first, to classify decision attributes on the basis of condition attributes and second, to form decision rules which are implication relationships between the description of the condition attributes and that of decision attributes. Decision rules can be seen as conditional statements of an 'if-then' nature. Rough set analysis basically evaluates the importance of attributes for a classification of objects, reduces all superfluous

[5] Formally, a rough set is characterized by the feature that it is not possible to tell a priori which objects belong to a given set, although it is in principle possible to identify all objects which may belong to that set (see for details, Van den Bergh et al., 1997, and for several applications e.g. Baaijens and Nijkamp, 1997).

objects and attributes, discovers most significant relationships between condition attributes and objects' assignments to decision classes, and represents these relationships e.g. in the form of decision rules (Slowinski and Stefanowski, 1993). Rough set analysis is clearly very appropriate in case of qualitative or categorical statements obtained in interviews. Therefore, we will apply rough set analysis for our empirical work.

In our rough set analysis a total of 273 firms appear to act as indiscernible objects. The decision attribute (dependent variable) is here whether or not a firm has innovated. Our investigation will focus on those condition attributes (local milieu factors) which in the above exploration turned out be the most important. The condition attributes (explanatory variables) are the following: 1) industry (SIC industries 17-19, 27-28, 29, 31, 33, 34, and the class 'rest'); 2) area (central, intermediate, and periphery); 3) competitive edge (innovativeness; cost-effectiveness; and marketing, financing, or other); 4) training links (yes, no); 5) commercial links (yes, no); 6) recruitment links (yes, no) with a local university; and 7) assistance (investment, training, or other) given by a local or regional institution. Production milieu variables (4-7) represent important local factors, i.e., various links of firms with local institutions (see above in Table 4).

As shown in the first row in Table 6, the condition attributes appear to allocate 69 firms to the class 'innovation' and 126 firms to the class 'no innovation' (lower approximations). This means that out of the total of 273 firms, 71.4 percent firms can be classified to either the innovative or the non-innovative category. An interesting rough set result is that all condition attributes turn out to belong to the core. In other words, there are no redundant attributes, which means that an exclusion of one of these features would reduce the accuracy of classification. This result tends to show that both the production milieu and structure are important attributes of innovativeness.

The relative importance of the attributes can be investigated by dropping at a time one of the attributes from the core. The lower rows in Table 6 show the number of classifications and the quality (percentage) of classifications when each attribute is excluded in turn. The second row indicates that when the attribute 'Industry' is excluded, the quality of classification is the lowest; then, only 30.4 percent of the firms can be classified. The result that the areal condition attribute is almost as an important attribute as the industry, tends to support our prior view on spatial variations of innovativeness (H_2). The quality of the classification decreases the least when the attribute 'Recruitment links' is excluded. Then, even 65.6 percent of the firms can still be classified.

Table 6. Lower Approximations for Rough Set Classes

N=273	Innovation	No innovation	Quality of classification
With core attributes	69	126	0.714
With a temporarily reduced condition attribute			
Industry	26	57	0.304
Competitive edge	45	86	0.480
Area	43	91	0.491
Training links	60	104	0.601
Assistance	56	110	0.608
Commercial links	56	112	0.615
Recruitment links	61	118	0.656

In general, although link attributes (milieu variables), namely training, commercial, recruitment and assistance attributes, tend to be less important than the others for the proper classification of the firms in terms of innovativeness, they belong yet to the core and are necessary for a high quality classification. In other words, the above rough set results clearly indicate that production milieu tends to affect the innovativeness of firms in a region, a finding which supports our seventh hypothesis (H_7).

6.2. Logit analysis

We will now offer an explanatory analysis for the firm's innovative behaviour by applying a logit analysis. We model innovativeness by industrial, areal and production milieu variables in order to test our previous hypotheses (except the fifth one). Logit analysis cannot be applied to the testing of hypothesis H_5, because our data set does not include separate measurable variables for product and process innovations.

In our data set on industrial attributes only 0-1 categorical variables are available, so that no other information than dummy variables is available. Variables which begin with IND... (e.g. IND1719DUM) are dummies for the 6 selected industries. CITYPERI and CITYINTE are the 2 areal dummies for the firms in the peripheral and intermediate areas, respectively. ED-GEDUM is the dummy for the firms having product innovativeness as the competitive edge in the near future. The urban milieu variables mainly represent those local factors, which were commonly found to be important among firms surveyed, viz. various links of firms with local institutions. A variable which begins with LINK... is one of the 3 dummies for the industries which have commercial (LINKCOMM), training (LINKTRAI) or recruitment (LINKRECR) links with a local university or college. The possible impact of commercial (consultancy, testing, subcontracting, joint ventures) and training links is more easily justified than that of recruitment links, because they directly correspond to two commonly and highly valued local factors, viz. ’Skills training support’ and ’Science and technology links’. Nevertheless, we do not wish to exclude the dummy for recruitment links a priori. Finally, ASSTRAIN is the dummy for firms which have received training assistance from a local (or regional) public sector institution or agency[6]. In sum, we have altogether 13 dummy variables in our data set.

We will first model the propensity to innovate by using all 13 dummies which reflect industrial structure, location, or local factors. We will use here Theil’s sequential elimination procedure, by discarding one redundant variable at a time from the equation beginning with the most insignificant variable (Theil, 1971). This reduction procedure will be continued until only statistically significant regressors are left in the explanatory model.

The above described procedure leads to the specification shown in Table 7. Results imply that the relatively more innovative (younger) industries contribute significantly to the propensity of a firm to innovate. The less innovative (older) industries do not contribute to the innovation propensity. We recall here that SIC-industries 17-19 and 27-28 are less innovative and that 29, 31, 33, and 34 are more innovative industries. Thus, it is interesting to observe that this outcome confirms the results obtained in the descriptive analysis and supports the first hypothesis (H_1).

Table 7. Innovation as Dependent Variable

-2 Log Likelihood: 367.30157 (restricted model)
-2 Log Likelihood: 323.413 (full model)

-Variable-	B	S.E.
IND29DUM	1.0613	.3427
IND31DUM	1.2892	.4229
IND33DUM	1.2720	.5115
IND34DUM	2.0964	.5507
LINKTRAI	.9312	.2799
Constant	-1.6011	.2635

Note: B=estimated coefficient and S.E.=standard error

Spatial dummies are apparently not significantly related to the innovation propensity of all firms, which implies that firms in a given area are not necessarily more innovative than firms in other areas (see Table 7). Below we will test whether or not regionally discriminating differences can be found at the industry level, i.e. whether or not we can find results that

[6] Due to an incomplete data set, our logit analysis had to exclude a few indicators on production structure which may be expected to affect the propensity to innovate (such as size, market power and growth rate of a firm).

support our second hypothesis. These differences would imply a specific locational pattern for the industries concerned.

An interesting result in Table 7 is that firms with innovativeness as the competitive edge in the near future have apparently not significantly more often innovated in the past than the others. A plausible reason for this result, which is different from that obtained by rough set analysis, is that in the rough set analysis the attribute ’Competitive edge’ includes - besides product innovativeness - also cost effectiveness, marketing and financing as a competitive edge factor. In the logit analysis the corresponding ’Edge’ variable was a normal dummy variable representing only innovativeness as the competitive edge. This result calls for further empirical investigation.

Training links appear to be positively related to innovativeness, but commercial or recruitment links are not (see Table 7). This indicates that at least such local factors as training links with a local university tend to contribute to innovations, a result which partially supports our seventh hypothesis (H_7). This also complies with the above obtained results that ’milieu’ factors, which affect innovativeness of firms, are not equally important. In particular, this result is in line with the previous finding that firms regard skills training support more often as an important local factor inducing innovations than science and technology links (commercial links) or managerial links with the local university. It also turns out that training support from other local or regional institutions is not a statistically significant regressor either. This implies that skills training support offered by a university tends to be more important than that offered by other skills training institutions. A related question is now for which industries the most imprtant factor, viz. training links, contributes to innovativeness. It is also an important question whether the other links (commercial and recruitment) contribute to innovativeness in any industry. In other words, we are interested in finding out a possible confirmation for our sixth hypothesis and further support for our seventh hypothesis.

We will now test our second hypothesis (H_2); in other words, we will investigate whether or not the industries have any specific locational pattern. We will do so by splitting all variables for the 6 selected industries into central, intermediate and peripheral classes by adding separate dummies for industries in those areas to the explanatory morel concerned. For instance, we will add three separate variables for firms in industry 34. One dummy concerns firms in central areas, a second one is the dummy for firms in intermediate areas, and a third dummy is for firms in peripheral areas. Similarly, we will add three separate dummies which will represent firms in the distinct areas with a training link variable, because the training link variable was also a significant regressor in the specification shown in Table 7. The model reduction procedure is the same as above, and the results of our logit model are given in Table 8.

The results in Table 8 suggest that the firms in industry 29, 31 and 34 tend to innovate more often when they are located in intermediate areas. This result is in accordance with the previous findings of the descriptive analysis, and support the second hypothesis (H_2). For the remaining 'innovative' industry (33), firms in all areas contribute to the innovation propensity (see Table 7). The conceptual model and the results of the descriptive analysis would also imply that firms in the less innovative (older) industries would innovate less often when they are located in central areas than otherwise. This plausible assumption however, does not seem to be entirely valid. Centrally located firms in basic materials and fabricated metal product industries (firms in industries 27-28) are apparently not less innovative than firms in the same sector located elsewhere. On the contrary, the logit model seems to suggest that firms in the textile, wearing and leather industries (SIC-industries 17-19) would innovate less often when they are located in peripheral areas, a result which contradicts the second hypothesis but is in accordance with the findings in the exploratory analysis and with the findings concerning the locational patterns of these sectors in the 'Third Italy', because this means that the technogenesis of new design and innovations in the textile and wearing industries are not taking place in the periphery.

Table 8 also indicates that skills training links with a local university contribute more to innovativeness compared to a situation where a firm has no training links or does have them in intermediate areas. The positive impact of links in central areas is plausible, given that universities in central areas are likely more effective than those in intermediate areas. However, the result that also links in peripheral areas would be more profitable to innovativeness than those in intermediate areas, is harder to interpret and would deserve further empirical research.

Table 8. Innovation as Dependent Variable

-2 Log Likelihood: 367.30157 (restricted model)
-2 Log Likelihood: 331.036 (full model)

-- Variable --	B	S.E.
CITYINTE*IND29DUM	1.2445	.6134
CITYINTE*IND31DUM	1.8888	.7013
CITYINTE*IND34DUM	2.4121	.8028
CITYPERI*IND1719D	-2.2536	1.0823
CITYCENT*LINKTRAI	.7801	.3448
CITYPERI*LINKTRAI	1.3043	.3889
Constant	-.9080	.1829

Table 9. Innovation as Dependent Variable

-2 Log Likelihood: 367.302 (restricted)
-2 Log Likelihood: 310.698 (full)

-- Variable --	B	S.E.
IND33DUM*LINKTRAIN	3.0709	1.0717
IND29DUM*LINKTRAIN	2.4603	.5762
IND34DUM*LINKCOMM	2.1981	.6776
IND34DUM*LINKCOMNO	2.2469	.8177
IND31DUM*LINKCOMM	1.6873	.5708
IND29DUM*LINKRECRU	-1.7174	.8552
Constant	-.9942	.1608

We will now deal with our sixth (H_6) and seventh hypothesis (H_7). We can partly test these hypotheses by distinguishing the firms within each industry into two classes, viz. those with a link (LINKTRAIN, LINKCOMME and LINKRECR) and those without a link (LINKTRNO, LINKCONO and LINKRECNO). This subdivision is made for all three links, namely training, commercial and recruitment links. After the model reduction procedure the estimation results are given in Table 9. This table prompts us to make the following comments.

The firms in the industries 29 and 33 with training links appear to innovate more often than the firms in the other industries with training links and the firms in the same industries without training links (see Table 9). This implies that training links are more important for the relatively more innovative (younger) than for less innovative (older) industries, and thus gives partial support to the sixth hypotheses. The firms in the industry 31 with commercial links tend to innovate more often than the firms in other industries or in the same industries without commercial links. On the one hand, firms in industry 34 with commercial links appear to be more innovative than firms in other industries with commercial links and firms in the same industry without commercial links. On the other hand, also an opposite result is found: firms in industry 34 without commercial links turn out to be more innovative. These results imply that commercial links do not play a decisive role in the car manufacturing industry (34), but play also a role in the electronics industry (31). Nonetheless, this implies that also commercial links are more important for the relatively younger than for older industries, which also renders partial support to the sixth hypothesis. Also the seventh hypothesis is partly supported by these results, which indicate that such local factors as training and commercial links with a local university influence the innovativeness of firms.

Table 9 also shows that firms in industry 29 with recruitment links tend to innovate less often than firms in other industries with such links and firms in the same industry without recruitment links. This does not seem to be the case for other industries. These results tend to suggest that for one of the younger industrial sectors the recruitment links would have even a negative effect on innovativeness, a finding which implies a low importance of recuitment links for innovativeness.

Finally, we will test our third (H_3) and fourth (H_4) hypothesis. In order to test these hypotheses, we have to change our dependent variable. Our dependent variable is then: ’innovativeness as competitive edge’, which also is a 0-1 dummy. Table 10 shows results after the model reduction procedure (initially all 6 industry dummies were included in the model). Table 10 indicates that firms in the less innovative (older) basic materials and fabricated metal manufacturing sectors (SIC 27-28) have a lower propensity for innovativeness as competitive edge than firms in other industries. Moreover, Table 10 shows how firms in more innovative (younger) electronics and car manufactuing industries (SIC 31 and 34) have a higher tendency for innovativeness as their competitive edge than firms in other industries. These findings support our third hypothesis.

Finally, Table 11 is obtained after splitting all 6 industries into central, intermediate and peripheral classes and after having carried out the reduction procedure. Results here are not as robust as above. On the one hand, the result that firms in a more innovative (young) industry (SIC 34) tend to use innovativeness more likely as a vehicle for their competitive edge when they are located in intermediate areas than otherwise, is in accordance with our fourth hypothesis. On the other hand, we find also an inconclusive result: the fact that firms in another young industry (SIC 31) regard innovativeness as their competitive edge more often when they are located in the periphery contradicts with the hypothesis. This finding calls obviously for more detailed research.

Table 10. Dependent Variable: Innovation as Competitive Edge

-2 Log Likelihood: 378.1616 (restricted model)
-2 Log Likelihood: 352.068 (full model)

-- Variable --	B	S.E.
IND2728DUM	-0.9929	0.4354
IND31DUM	0.9318	0.4555
IND34DUM	0.1567	0.5715
Constant	-0.0632	0.6634

Table 11. Dependent Variable: Innovation as Competitive Edge

-2 Log Likelihood: 378.1616 (restricted model)
-2 Log Likelihood: 359.760 (full model)

-- Variable --	B	S.E.
CITYPERI*IND31DUM	2.4799	1.0521
CITYINTE*IND34DUM	2.3826	1.0564
Constant	-0.0800	0.1233

7. Concluding Comments

The present study has dealt with an ideal-typical model of spatial innovation processes, based on product life-cycle and incubation approaches. Our cross-sectional results tend to show that the spatial innovation behaviour is largely in accordance with the patterns implied by the phases of the industrial life-cycle (H_1 and H_2). On the basis of spatial innovativeness, we may conclude that especially the two-digit industries 27-28 tend to live in the stagnation phase of their technological life-cycle, while the industry categories 29, 31, 33, and 34 tend to live in the competition phase of their life-cycles. Intuitively, this is an appealing result, because, for instance, the firms manufacturing basic materials and fabricated metal products - except machinery and equipment (27-28) - do likely belong to more mature industries than the firms manufacturing electrical machinery and apparatus (31). These results were obtained by both our exploratory analysis and the logit analysis (see the findings in Table 12 for a general survey).

Our conceptual model and the empirical findings have implications for regional economic development. First, we may argue that at the begining of the industrial life-cycle, the innovativeness would be relatively highest in central areas. This implies that centralizing forces are in effect during that phase. Second however, when the industrial life-cycle reaches its later phases, then decentralizing forces take over, as implied by relatively higher innovativeness of firms in those areas during later phases of a life-cycle. A great deal of empirical evidence has been found elsewhere for this so-called convergence hypothesis within industrialized countries and regions within one country (see e.g. Barro and Sala-i-Martin, 1995 and Kangasharju, 1997).

Table 12. Summary of the Results

Hypotheses	Exploratory	Logit	Rough set
H_1: *an industry produces more innovations in earlier phases of its life-cycle.*	+	+	o
H_2: *the phase of the life-cycle of an industry can be identified on the basis of the relative innovativeness of firms in distinct relevant area categories.*	+	+	o
H_3: *product innovations serve more commonly as a competitive edge in the younger industries than in older ones.*	+	+	o
H_4: *the phase of the life-cycle of an industry can be identified on the basis of how broadly the product innovativeness serves as a competitive edge of firms in distinct area categories.*	-	-	o
H_5: *local factors are more important for product than for process innovations.*	+	o	o
H_6: *local factors are more important for a younger than for an older industry.*	+	+	o
H_7: *the local 'production milieu' has a positive impact on innovativeness of firms in an area.*	+	+	+

Note: '+' denote confirmatory findings, '-' denote contradictory findings, and 'o' denote situations where particular test method was not used.

Our empirical results for the competitive edge were less satisfactory (H_3 and H_4 in Table 11). Although we saw that more innovative (younger) industries regard innovativeness more often as the competitive edge than less innovative (older) industries, a finding which supports our third hypothesis (H_3), the spatial results do not unambiguously support our conceptual model, however. In this context, it was hard to identify a clear regional pattern, especially in the case of the more innovative industries (H_4). It is clear that more research is needed to shed light on the spatio-temporal dynamics of firms' strategic behaviour.

Finally, empirical results for the importance of local factors supported the hypotheses derived from the conceptual model (H_5, H_6 and H_7). The exploratory analysis produced some evidence that local factors are considered as more important for product than for process innovations and that they are more important for more innovative, younger industries than for less innovative, older industries. We also saw that a possible cooperation of firms with a university may incorporate those factors, which were most commonly mentioned as important, viz. skills of the labour force by training links, and science and technology links. The logit analysis revealed that among those links with universities, especially training links tend to be more important for innovativeness than commercial or recruitment links, a result which leads to a policy recommendation on the significance of increased schooling and training expenditures. All rough set, logit and exploratory correlation analyses produced also some evidence that the production structure of regions would not entirely govern the innovativeness of regions, but also some local factors appear to affect innovativeness of firms, which implies that also the production 'milieu' component affects innovativeness of regions. In other words, firms in peripheral (rural) areas can compensate for their peripherality (lack of agglomeration economies etc.) by active cooperation with universities. Similarly, this calls for actions by local and regional governments to improve the local business environment.

Acknowledgements

This study was a part of a research project funded by the Academy of Finland. The authors wish to thank Marina von Geenhuizen, Tomaso Pompili and Peter Townroe for their assistance in collecting the data.

Annex 1. Industries in the Questionnaire

SIC codes	Name
15-19	Food and beverage (15), tobacco (16), textiles (17),wearing apparal, dressing and dyeing of fuhr (18), tanning and dressing of leather: luggage, handbags, saddlery, harness and footwear (19).
20-29	wood, wood products, cork, except furniture: articles of straw and plaiting materials (20), paper and paper products (21), publishing, printing and reproduction of recorded media (22), chemicals and chemical products (24), rubber and plastics products (25), basic materials (27), fabricated metal products, except machinery and equipment (28), machinery and equipment (29).
30-39	electrical machinery and apparatus (31), radio, tv and communication equipment and apparatus (32), medical precision and optical instruments, watches and clocks (33) motor vehicles, trailers and semi-trailers (34), other transport equipment (35), furniture and manucaturing n.e.c. (36), recycling (37).
Other	Electricity, gas, steam and hot water supply (40), construction (45), sale, maintenance and repair of motor vehicles and motor cycles; retail sale of automative fuel (50), post and telecommunications (64), computer and related activities (72).

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