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Towards a Dynamic Theory for the Spatial Knowledge Economy

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ABSTRACT

In recent decades the world has witnessed the emergence of a global knowledge economy. For example, the evolution in recent decades of the developed economies has been accompanied by a regional shift in economic activity away from traditional industrial regions to new agglomerations of high technology, creating an explosion of entrepreneurial activity and new firm formation. For the OECD countries in particular, we can observe a transfer from an industrial economy to a knowledge economy. The supporting evidences are overwhelming and indicate that the trend is global. The emerging knowledge economy have attracted much interest among economist and generated many important contributions during the last two decades. However, the literature does not provide a comprehensive picture and we are indeed lacking a “general theory” of the knowledge economy. Various aspects of the emerging knowledge economy has been thoroughly analysed both theoretically and empirically but the overall synthesis is not yet present. Something to ask for would be a coherent theoretical framework that can explain how growth-induced investments in knowledge production stimulate localised, entrepreneur-driven innovations, which generate structural change and economic growth in an integrated system of functional regions. An interesting observation is that many of the necessary building blocks already seem to exist but that they are still waiting for someone to integrate them. The current state-of-the-art also includes inconsistent components. The purpose of this paper is to contribute to such an integration of the existing pieces of knowledge.

Keywords: Knowledge, Economic Growth, New Economic Geography, Innovation Systems, Entrepreneurship

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1. INTRODUCTION

In recent decades the world has witnessed the emergence of a global knowledge economy. For example, the evolution in recent decades of the developed economies has been accompanied by a regional shift in economic activity away from traditional industrial regions to new agglomerations of high technology, creating an explosion of entrepreneurial activity and new firm formation (Acs, Carlsson & Karlsson, 1999, eds.). For the OECD countries in particular, we can observe a transfer from an industrial economy to a knowledge economy. The supporting evidences are overwhelming and indicate that the trend is global. A series of observations point in the same direction and can be summarised as follows:

- Changing industry composition
- Changing composition of international trade
- Changing location of production
- Changing occupational structure of employment
- Changing educational structure of employment
- Growing knowledge intensity of the labour force in the OECD countries
- An increasing number of goods and service varieties
- Increasing investments in knowledge production.

Not surprisingly, the above change processes in the emerging knowledge economy have attracted much interest among economist and generated many important contributions during the last two decades. However, the literature does not provide a comprehensive picture and we are indeed lacking a "general theory" of the knowledge economy. Various aspects of the emerging knowledge economy has been thoroughly analysed both theoretically and empirically but the overall synthesis is not yet present. Something to ask for would be a co-herent theoretical framework that can explain how growth-induced investments in knowledge production stimulate localised, entrepreneur-driven innovations, which generate structural change and economic growth in an integrated system of functional regions. An interesting observation is that many of the necessary building blocks already seem to exist but that they are still waiting for someone to integrate them. The current state-of-the-art also includes inconsistent components. The purpose of this chapter is to contribute to such an integration of the existing pieces of knowledge.

The presentation starts with a brief enquiry into the concept of knowledge as such and an assessment of its role in economic theory. As a second step, economic growth is characterised as a knowledge-driven process. This leads to questions in Section 3 about the geography of knowledge and proximity-based externalities. Section 4 elaborates knowledge flows and spillovers in regional and global innovation networks. All this brings us to Section 5, which assembles the different components around the entrepreneur as a gravitation centre.

2.KNOWLEDGE IN ECONOMIC THEORY

A review of the economics literature dealing with knowledge suggests that some authors use the term knowledge in their analysis, while others use information as a label. There are good reasons to complain about this, because a distinction between the two concepts of knowledge and information lead to analytical advantages. In view of this, one may observe that many authors do not define the specific concept that they refer to. Even worse, some authors use the two concepts interchangeably. This state of affairs makes it quite difficult to evaluate the different contributions - whether they are theoretical or empirical in scope.

Why is it then vital to make a clear-cut distinction between information and knowledge? The most important reason is that information flows are characterised by low friction whereas the opposite applies to knowledge. We suggest that information should be defined as such data that can be easily codified and therefore transmitted, received, transferred, and stored at low costs (Kobayashi, 1995). This implies that information can be accessed and disseminated electronically, for example via the Internet. Thus, information consists of those uncomplicated messages (or superficial aspects of messages) that have the form of standardised data, which are easy to manipulate and to store, for either a longer or a shorter time (Kobayashi, Sunao & Yoshikawa, 1993).

Knowledge, on the other hand, consists of organised or structured information that is difficult to codify and interpret, generally due to its intrinsic indivisibility. As a consequence, knowledge is difficult to transfer without direct face-to-face interaction. Loosely speaking, when knowledge is transferred from one person to another they both have to calibrate their explanation and interpretation activities. In this way face-to-face contacts become a necessary or facilitating condition, though not a sufficient condition, for knowledge transfer. Von Hippel (1995) persuasively demonstrates that highly contextual and uncertain knowledge, i.e. what he refers to as "sticky knowledge," is best transmitted via (preferably frequent) face-to-face interactions. This is in line with the claim by Teece (1998) that knowledge assets are often inherently difficult to copy. Proximity matters in connection with sticky knowledge because, as Arrow (1962) points out, such knowledge is generally non-rival, and the knowledge developed for any particular application can easily spill over and find additional applications, if the obstacles to communication are not too substantial.

Von Hippel's sticky knowledge is also referred to as tacit knowledge in many studies from the last decade. In association with this, one may reflect a little bit further on different types of knowledge. Figure 1.1 illustrates a decomposition of knowledge into (i) "know-how", and (ii) "know-why". The first of these refer to skills such as playing the violin, riding a bike or employing an econometric method or statistical programme. The "know-why" form of knowledge rather focuses on the model of the vibrating string or the rules of composing to explain why the violin sounds the way it does and why the music has to be arranged in certain ways. To know why an econometric method works one may have to apply the statistical theory behind an econometric method.

In view of the above examples, skills and know-how are typical examples of tacit knowledge that cannot be meaningfully codified but have to be learnt by training and ideally also with the help of somebody showing or illustrating how to treat the strings, how to keep the balance of the cycle or how to apply a statistical programme. Know why, on the other hand is rather characterised by complexity and systemic features, although tacit-knowledge aspects may also be present.

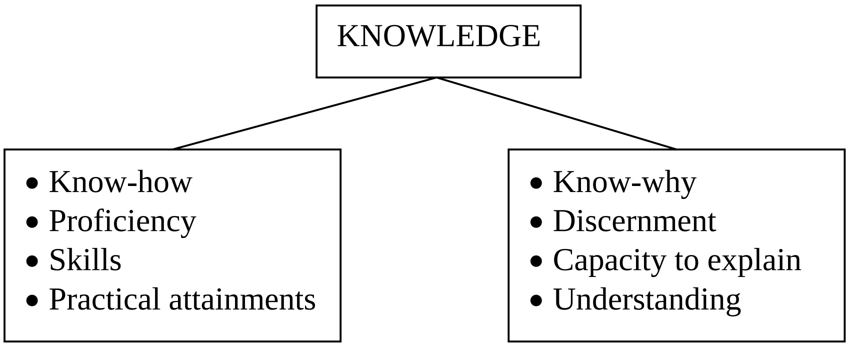

Figure 2.1: Two categories of knowledge

While the costs of transmitting information may be close to invariant with respect to distance, the cost of transmitting knowledge increases together with the distance. Since the transmission of knowledge requires face-to-face contacts, knowledge exchange requires an extensive amount of somewhat diffused movements throughout various transportation networks.[2] Knowledge exchange is an essentially interpersonal activity that is defined here as any action that can contribute to the process of the disclosure, dissemination, transmission, and communication of knowledge. This presupposes that knowledge is neither shared ubiquitously nor passed around at zero cost (Teece, 1981).

Obviously, there are costs and fundamental difficulties in transferring knowledge. It explains why markets for exchange of knowledge are rare. Potential buyers may question the value of the knowledge, and sellers cannot easily assuage their concern without revealing their valuable asset – the specific knowledge. The buyer's and the seller's transaction information is intrinsically asymmetric. It also explains why firms prefer – in principle – to carry out R&D in-house rather than having it contracted out or licensed (Soete, 2001). It also provides a rationale for policies focusing on the importance of investments in knowledge accumulation. Such investments are likely to have 'social' rates of return that often are much higher than the private rates of return. This observation implies that investments in knowledge cannot simply be left to the market, if growth and efficiency are important criteria.

In terms of economic theory, knowledge is not restricted to the technical aspects of know-how for firms but also includes components such as institutional and organisational know-how. A comparison of the knowledge concepts used in endogenous growth theory, on the one hand, and in regional economics and economic geography, on the other hand, reveals that the pertinent concepts are quite different. In endogenous growth theory, knowledge is normally defined as the result of a gradual accumulation of knowledge that plays the role of a productivity enhancing production factor. Knowledge is generated in two principle ways: (i) it can be an output from a knowledge production process with R&D as the input, and (ii) it can have the form of knowledge accumulation that is caused by learning-by-doing.

[2] Historically, the transfer/communication of rich information has required proximity and specialised channels to customers, suppliers, and distributors. However, we must acknowledge the possibility that the new developments are undermining the traditional chains and business models, and that new structures – generally less dependent on physical communication channels – might become more and more often an economically viable option (cf. Teece, 1998).

In contrast to standard endogenous growth theory, regional economics and economic geography authors often work with a knowledge concept that adheres to Marshall's ideas, which comprise a much broader concept. In the case of Marshall as well as Schumpeter, knowledge includes phenomena such as market and organisational knowledge. Contributions in recent decades have in particular elaborated and examined the complexities of the generation and diffusion as well as use of knowledge in economic activities.

In view of the above exposition, it seems useful to distinguish three knowledge concepts:

1. Scientific knowledge in the form of basic scientific principles that can form a basis for the development of technological and entrepreneurial knowledge.

2. Technological knowledge – implicit and explicit blueprints – in the form of inventions (or technical solutions) that either materialise in new products or can be readily used in the production of goods and services.

3. Entrepreneurial knowledge that comprises business relevant knowledge about products, business concepts, markets, customers, and so on.

In concordance with Schumpeter's analysis, scientific knowledge functions as a background to or platform for technological and entrepreneurial knowledge in the innovation process (Schumpeter, 1934). As suggested by Nelson & Winter (1982), a firm's innovation can be a change in the routines (technique, organisation, etc.) of the firm and/or a new product (e.g. a change in attributes of a good or a service). In both these cases an innovation is the combined result of technological and entrepreneurial knowledge.

In dealing with the different concepts of knowledge it is essential to characterise them according to the degree to which they are *rivalrous* and *excludable* (cf., Cornes & Sandler, 1986). A purely rivalrous good has the property that its use by one firm or person precludes its use by another, whereas a purely non-rivalrous good has the property that its use by one agent in no way limits its use by another. Excludability relates to both technology and legal systems (Kobayashi & Andersson, 1994). A good is excludable if the owner can prevent others from using it. While conventional goods are both rivalrous and excludable, pure public goods are both non-rivalrous and non-excludable.

Scientific knowledge has the character of a pure public good, although it is generally only available to those with the relevant scientific training. Hence, access to scientific knowledge can differ between firms and between regions, due to an unequal supply of scientifically trained labour. However, legal restrictions can also be imposed, at least for commercial applications. This is illustrated by the increased propensity in recent years to try to patent basic scientific discoveries in e.g. biotechnology (*The Economist*, April 8th, 2000).

Technological knowledge may be perceived and even deliberately created as a non-rivalrous, partially excludable good (Romer, 1990). Its non-rivalrous character stems from the fact that technological knowledge is inherently different from other economic goods. Once the costs of creating new "technological knowledge" have been incurred, this knowledge may be used over and over again at no additional cost. It is in this sense that technological knowledge is non-rivalrous. The partially excludable character of technological knowledge stems from the fact that firms generally protect new inventions by having patents issued on them. However, patent applications – and therefore patents - must be quite detailed. This opens up opportunities for the competitors to imitate or to "invent around" patents, so that as a matter of fact technological knowledge *may* be accessible for intellectual purposes. At the same time, investigation and imitation activities consume resources. This implies that there is a cost or friction element in the process of imitating.

Entrepreneurial knowledge is most often the result of learning-by-doing, and can generally be viewed as a non-rivalrous, partially excludable good. Although the accumulation of entrepreneurial knowledge is more of an experienced-based process, it can be assumed to involve R&D-like costs. The access to entrepreneurial knowledge can be limited in various ways, for example by attempts to preserve "business secrets." There appears to be a growing tendency also to protect business ideas by means of patents (*The Economist*, April 8th, 2000).

The processes by which the different types of knowledge are made available by their creators to other individuals or firms take place in spatial networks, i.e. "knowledge networks" (Batten, Kobayashi & Andersson, 1989; Kobayashi, 1995) consisting of a set of nodes and a set of links connecting them. At a coarse spatial resolution these nodes are represented by human settlements such as towns, cities and metropolitan regions, providing different instances of functional regions.[3] At finer geographical scale we can observe network links between firms and even individuals. The nodes can be characterised by their endowment of knowledge production capacities and related activities, including knowledge infrastructure such as universities, meeting infrastructure, stocks of knowledge and human capital, local knowledge networks, and so on. The links include transportation as well as communication channels. The spatial perspective adds a further dimension to knowledge transfers. Partial excludability of the new knowledge is not only a result of patents, business secrets, and so on but also a consequence of limited physical accessibility.

Much of the discussion and analysis of knowledge flows has become contaminated because of unclear and fuzzy definitions of pertinent flows. In particular, many scholars have employed the concept pf spillovers in an unfortunate way (Echeverri-Carrol 2001; Gordon & McCann, 2000). As a step towards more clarity and precision in the analysis, we suggest a separation into the three groups of knowledge flows: (i) transaction based knowledge flows, (ii) transaction related knowledge flows, and (iii) knowledge spillovers. Table 1.1 presents these three categories and identifies eight types of knowledge flows.

[3] Functional regions are delimited based upon the spatial interaction patterns of the economic agents in a country. A functional region is fundamentally characterised by its size, by its density of economic activities, social opportunities and interaction options, and by the frequency of spatial interaction between the actors within the region (Johansson, 1997).

Table2.1: Classification of knowledge flows to a firm

Transaction-based flows	1. Flows from knowledge providers that sell knowledge that is used as an input to the firm's R&D activities 2. Flows in the form of inventions (innovations) that are sold to the firm (e.g. by licensing a patent) 3. Knowledge flows between firms that cooperate in an R&D project, where costs and benefits are regulated by explicit or implicit contracts.
Transaction-related flows	4. Flow of knowledge that is embodied in the delivery of inputs from an input supplier to the firm 5. In the course of supplying inputs to the firm, knowledge from the input supplier spills over unintentionally to the input-buying firm. 6. In the course of supplying inputs to another firm, knowledge from the input-buying firm spills over unintentionally to the input-selling firm.
Spillover flows	7. Unintentionally, knowledge spills over from one firm to a competing firm in the same industry. 8. Unintentionally, knowledge spills over between firms belonging to different industries.

The distinctions made in Table 1.1 are important for several reasons. First, when the flows are transaction-based the participating economic agents have – in their own hands – market-like instruments to influence the resource allocation. Second, the mechanisms that generate the flows are different for the three main categories which have implications for policy formation. Third, the externalities that can arise in all eight cases vary in nature (e.g. pecuniary and non-pecuniary) and should not be confused with each other. In the subsequent analysis we shall make use of the distinction when discussing innovation networks and proximity externalities.

3. KNOWLEDGE-DRIVEN ECONOMIC GROWTH

A natural starting point for gaining an increased theoretical understanding of the emerging knowledge economy is the new endogenous growth theory, which emphasises the role of the stock of accumulated knowledge and the growth of this stock. It suggests that continuous increases in technological knowledge (Romer, 1990) or in human capital accumulation, i.e. the embodiment of knowledge in human beings (Lucas, 1988) are the driving force behind economic growth. However, it takes for granted that economic growth is not emerging automatically as 'manna from heaven', but is the result of deliberate actions and choices of various stake-holders, including the government (Nijkamp, 2003). Lucas' conceptualisation of the process by means of which human capital is built up is simple and founded on straightforward principles. Economic agents decide according to their preferences about the allocation of their non-leisure time between current production and the accumulation of human capital, and thereby they also determine the growth rate of output. If the time spent on current production is reduced, current output is reduced but at the same time the decision speeds up the formation of human capital and thus increases future growth. The Lucas approach includes an externality in the sense that the more human capital society as a whole has accumulated, the more productive each individual member of society will be.

A distinguishing feature of the Romer approach is the modelling of technological progress as a result of profit-motivated investments in production of technological knowledge by private economic agents. These economic agents are acting in an economic environment characterised by monopolistic competition along the lines suggested by Dixit & Stiglitz (1977), which explicitly considers the trade-off between the output of goods and their variety. Markets are assumed to be imperfectly rather than perfectly competitive, because investments in R&D are feasible only if price exceeds production cost by some margin. Another distinguishing feature is the existence of increasing returns, since technological knowledge is treated as a non-rival, partially excludable good. Firms are able to maintain ownership of at least a portion of the value of the increased productivity or better product performance won through their R&D (Nelson, 1997). In such a framework, each firm that develops new technological knowledge gains some market power and thus can earn some monopoly profits on its investments.

New technological knowledge is used in two ways in the economy:

- It is used in the production of a specific unique product by the firm that developed it. The use of this specific knowledge by another firm for producing the same product can be protected by means of, for example, patenting.

- It increases the total stock of technological knowledge and may spillover to other firms investing in the production of technological knowledge by means of, for example, examinations of patent documentation (Romer. 1990). In this way it increases the productivity of knowledge production in the economy and it may very well be so that new knowledge benefits others as much or even more than they benefit the creator of the new knowledge (Quigley, 1998).

A limiting factor with the original Romer-approach is the assumption of general accessibility of the stock of technological knowledge across space. We have strong reasons to believe that the stock of technological knowledge is not evenly accessible across countries or even across functional regions within countries. As shown in an early contribution by Andersson & Mantsinen (1980) a multiregional economy has a long-run growth equilibrium that is clearly influenced by each region’s accessibility to the knowledge accumulated in each region. In the adjustment towards an equilibrium path the regional growth will develop in region-specific space-time paths in response to differences between the knowledge accessibility of each region. Moreover, a reduction of the distance friction between any pair of regions will speed up the growth of the entire economy.

The accessibility considerations are essential, because new technological knowledge is often extremely complicated and contains tacit elements which imply that it often is accessible only via interaction within either inter-firm innovation networks or general innovation systems that tend to be bounded by geographical proximity (Karlsson, 1997; Karlsson & Manduchi, 2001; Andersson & Karlsson, 2004 a & b). Of particular concern is also the volume of human capital engaged in the generation of new ideas, innovations and technologies. The implications of these factors are far-reaching. Functional regions will differ not only in terms of their production of and access to technological knowledge but the mix of technological knowledge will also be different between functional regions. Thus, important elements of the production of technological knowledge will tend to be regional rather than national. This will probably have its strongest effects on science-based and high-technology industries but will in principle influence all industries. Hence, it is natural that in the regional development literature, the geographical distribution of knowledge workers is hypothesised to be a key driver of existing and future patterns of regional growth (Nijkamp & Poot, 1998; Bal & Nijkamp, 1998; Mathur, 1999; Florida, 2000 & 2002). This implies that the kinds of work (production activities) the regional economy carries out deserve at least as much attention as the kinds of products it makes (Thompson & Thompson, 1985 & 1987; Feser, 2003).

Recently, some economists have suggested an important link between national economic growth and the concentration of people and firms in large urban regions. The high concentration of people and firms in large urban regions creates an environment in which knowledge moves quickly from person to person and from firm to firm. This implies that large, dense locations encourage knowledge diffusion and knowledge exchange, thus facilitating the spread of new knowledge that underlies the creation of new goods and new ways of producing existing goods (Carlino, 2001). However, endogenous growth models, like all equilibrium models, are aimed at identifying the various growth factors and measuring their respective contributions to growth, so as to be able to derive policy conclusions (Amendola & Gaffard, 1998). Hence, there is only an implicit understanding of the working of the growth mechanisms, which are assumed in the models. The actual and concrete operation of these mechanisms has important bearings on the effective evolution of economies, though, and even more so on policy conclusions. In the sequel, we discuss how some of these mechanisms function in a spatial perspective, with a special focus on the role of entrepreneurial dynamics.

4. KNOWLEDGE DYNAMICS IN THE ECONOMIC GEOGRAPHY

The observations made above suggest that we – in our attempts to understand the emerging knowledge economy – need a theoretical framework that accounts for the fact that the production of technological knowledge is localised and that functional regions vary in terms of both the extent and the type of their knowledge production. This ambition fits very well into the theory labelled new economic geography (NEG), which has as its starting point the observation that economic activities are not evenly distributed across space, and that thus functional urban regions and not countries are the natural units of economic analysis. By using different versions of a general equilibrium model with the interrelations between three variables – increasing returns due to scale economies, transport costs and the demand for manufacturing goods – as its cornerstone, the NEG theory explains why economic activities concentrate in certain regions and not in others (Krugman, 1991 a; Fujita, Krugman & Venables, 1999; Johansson, Karlsson & Stough, 2001, Eds.). The existence of scale economies is a basic explanation for the existence of cities and urban regions. Without scale economies production and other economic activities would be dispersed to save on transport costs (Quigley, 1998).

The models developed within the NEG framework combine assumptions of scale economies and monopolistic competition. As a consequence these models feature cumulative causation or, in another terminology, positive feedbacks. Two main types of two-region economic geography models can be distinguished:

- The first type of model – "the foot-lose model" – is based on the argument that once one of the regions has got some sort of advantage that makes it larger than the other region, manufacturing firms will be drawn to it (Krugman, 1991 a). The critical factor is the so-called home market effect, according to which the larger region makes it possible for manufacturing firms producing differentiated products to exploit the advantages of scale economies. When new manufacturing firms enter the larger region, mobile labour will be attracted to the same region and as a consequence its population will expand. This increases the strength of the home market effect even more, thereby stimulating a further influx of manufacturing firms and labour, and thus creating a virtuous circle of growth in the larger region. Simultaneously and as part of the same process, the smaller region will experience a continuous decline.

- The second type of model is based on vertically-integrated industries. Here it is the intermediate goods producers which are the engine of the regional growth process. Intermediate goods are delivered to manufacturing firms that produce a final-demand output under constant returns to scale. As the intermediate inputs get more differentiated, the productivity of the final-demand sector (manufacturing) increases. Because of this, a region is a more favourable location for the final-demand sector, the larger and more diverse the intermediate goods sector is, and the very same diversity depends on the size of the final-demand output. The manufacturing firms can gain further advantages in the form of lower costs of inputs as input producers locate close to the manufacturing firms, which benefit from an upstream externality. This implies that there are socially increasing returns as aggregate production rises and that large regions are more productive due to the external effects of the investments of input producers offering a diverse set of input goods and services (Quigley, 1998). An important conclusion here is that diversity and variety in producer inputs can yield increasing returns to scale, even though all individual competitors and firms earn normal profits.

Combining the two model types described above, we are confronted with a case where demand and supply externalities working through backward and forward linkages stimulate further concentration in the larger region. Manufacturing firms will be attracted to the larger region since it offers a larger home market effect and lower input costs. Moreover, places in which manufacturing firms concentrate will create a large home market for suppliers of intermediaries. Thus, the demand and supply externalities induce a cumulative causation process, where the location of new manufacturing firms and new input-producing firms in an integrated process reinforces existing externalities in the larger region (Johansson & Karlsson, 2001).

The basic new economic geography models provide a technique for analysing and explaining the concentration of economic activities in a two-region case as being induced by some initial combinations of some basic parameter values and attributes a fundamental role to the home market effect. In the case of more than two regions, rather than local demand, what matters is overall market access (Krugman, 1993 a). This creates a pattern of demand-driven specialisation where large central urban regions are net exporters of goods produced under increasing returns and imperfect competition (Fujita, Krugman & Venables, 1999).

The new economic geography models suggest that once a clustering process has started it will tend to reinforce itself by attracting more firms. The reason is that agglomeration due to external economies results in demand and supply conditions that are better in the cluster than in the smaller region and so promote the growth of incumbent firms and attract the entry of new firms. This growth and entry increases cluster strength and so promotes further growth and entry, which begins to accelerate once a cluster has reached a "critical mass" (Pandit, Cook & Swann, 2002). Below the "critical mass", there exists insufficient mass and interactions to achieve the advantages of a cluster and beyond that level, mass and interaction are sufficient for cluster advantages to exist (Colgan & Baker, 2003). Implicitly, the NEG models assume that the larger region contains a large enough supply of potential entrepreneurs who will establish new product lines, i.e. new firms, as soon as the market potential has become large enough or that firms move from the smaller region to the larger region when the home market increases in the larger region.

However, the new economic geography models in their current form cannot be used for modelling knowledge-based regional growth. One basic reason is that Krugman initially refused to model technological externalities. However, the literature on innovation systems convincingly shows that knowledge flows including spillovers are at the core of knowledge-led regional development. Actually, location is crucial in understanding knowledge flows, since knowledge has been found to be geographically concentrated (Audretsch & Feldman, 1996). In addition, the capacity to absorb flows of new technological (and entrepreneurial) knowledge is facilitated by geographical proximity (Jaffe, Trajtenberg & Henderson, 1993; Baptista & Swann, 1998). Already Marshall (1920) identified the exchange of ideas as a type of externality leading to the localization, or clustering, of economic activity. The exchange of ideas is often called technology spillovers and has been used by Henderson (1974) and others to develop explanations for the clustering of economic activity and for differences in income and productivity across geographic space.

We should at this stage emphasise that proximity is essential both for transaction-based, transaction-related and spillover flows of knowledge. This may be clarified as follows:

- Assume that the price of transaction-based knowledge flows is distance sensitive, which means that knowledge transactions inside a region are more favourable than interregional knowledge transactions. Given this reasonable assumption, a proximity externality will exist, which stimulates knowledge suppliers and knowledge buyers to locate in the same region.

- Assume that ordinary input purchases are distance sensitive. Then sellers and buyers of inputs will have an incentive to locate in the same region. As a consequence transaction-based knowledge spillovers will be proximity dependent.

- Pure knowledge spillovers are generally assumed occur as a part of extra-market social interaction, which is normally considered to be distance sensitive. This type of knowledge flow is also caused by employees who shift job from one firm to another and who bring knowledge with them as they move between firms. Thus, proximity externalities will be associated with pure knowledge spillovers.

Large regions offer special advantages in terms of knowledge flows and spillovers, since they combine the localisation of clusters in specific industries with industrial diversity, i.e. a range of different industrial clusters. This observation suggests the formulation of a NEG model, which considers the favourable conditions for knowledge flows in large regions. When such a region has achieved an initial advantage in knowledge production it will function as an attractor of knowledge creating and knowledge using firms, since it offers opportunities of taking advantage of increasing returns in knowledge production.

Although it is indeed true that firms compete and not regions, per se, there are still important regional production and knowledge advantages that are being pursued by many of the actors within each individual region (Stough, 2001). This leads to an important premise: technological and entrepreneurial knowledge and innovations, emerge uniquely out of regions not simply because one or the other was endowed with a certain initial stock of factors of production, but because many of the assets necessary to compete are created in the course of development of industries and clusters. These assets include technological and entrepreneurial knowledge, which are prerequisites for novelty-by-combination processes, and which facilitate the exploitation of production resources and the development of regional institutional innovations that are designed to create and sustain further advantages. Furthermore, many of these technological, entrepreneurial and institutional assets are not easily transferable.

It seems natural to suggest that it is the size of the regional market potential that determines the probability that new knowledge in the form of inventions will be turned into innovations. The underlying reason is that a large market potential increases the demand for knowledge intensive products. The probability of turning inventions into innovations can be assumed to increase with the size of a region, and this gives knowledge creating and knowledge using firms an extra advantage of locating in large regions. In addition, when more knowledge creating and knowledge using firms locate in the large regions this makes these regions more attractive for knowledge workers, and this fuels the cumulative process. As the market potential of a region expands, the attractiveness of the region continues to grow.

As large regions grow the increased demand for land, premises and knowledge labour will tend to drive up their prices.[4] It seems natural to assume that many activities and industries go through a life cycle along which development-related externalities are essential and discriminating only in the early development stages (Glaeser, et al., 1992). This implies that the pertinent activities become less dependent on development-oriented labour, specialised inputs and knowledge spillovers as they mature (Krugman, 1991 a), and thus there will be strong economic incentives for many of these activities and industries to leave the large and knowledge intensive regions and move to smaller regions to avoid the higher cost levels in these regions. Such relocation processes increase the opportunities for new activities to develop and grow in the large regions. Overall we can imagine a pattern where experimental and innovative activities are found in large diverse, cross-fertilising urban regions, whereas standardised production is decentralised to smaller more specialised (and lower cost) regions (Duranton & Puga, 2001).

5. KNOWLEDGE-BASED REGIONAL INNOVATION NETWORKS

The above discussion implies that central elements of the process of innovation are regional rather than national. This is very much in line with the suggestion by Krugman (1995) that as economies become less constrained by national frontiers, i.e. as globalisation spreads, they become more geographically specialised. Functional (urban) regions are increasingly regarded as the important nodes of innovation, production, consumption, trade and decision-making and play a critical role in the global modes of production and transportation (Nijkamp, 2003). Thus, innovation is a localised process and innovation systems tend to a high extent to be bounded within functional regions. A fundamental reason for this is the nature of the interaction in innovation systems. The exchange of complex knowledge demands face-to-face interaction, and intensive and frequent face-to-face interaction takes place mainly within functional regions, that for practical reasons may be approximated by commuting regions (Andersson and Karlsson 2004 a & b). People interact most frequently with those who live and/or work in close geographical proximity and with whom they share backgrounds, interests, education employer, affiliations, and so on, i.e. people in close social proximity (Sorensen, 2003). This kind of interaction or networking requires investments in social

[4] Explicit recognition of the land and labour markets and the necessity of commuting suggests that, at some point, the increased costs of larger urban regions – higher rents and higher wages arising from competition for space and labour and higher commuting costs to more distant residences – will offset the production (and consumption) advantages of diversity (Quigley, 1998).

communication, informal bonds, training and education. Building up networks and operating them effectively is a time and effort consuming activity. Geographical proximity strongly influences the durability of interaction links by reducing the costs of maintaining them.

Innovation networks may to a large extent be an intraregional phenomenon, which implies that large urban regions have a special advantage. Furthermore, multiregional and global innovation networks are also easier and less costly to establish and operate when the nodes in a network are located in large urban regions. Those regions tend to have an advantage with regard to virtually all sorts of communication networks.

5.1 Knowledge Spillovers and Innovation in Industry

In the case of knowledge flows (and spillovers) across firms, we must distinguish between intra- and inter-industry flows (Feldman & Audretsch, 1999). Here the relevant question is: "Does the specific mix of economic activities undertaken within any particular region matter?" This question is important because a recent debate has focused precisely on the mix of economic activities carried out within agglomerations, and on how externalities generated by knowledge exchange and spillovers are shaped by this mix. Despite the general consensus that knowledge spillovers within a given region stimulate dynamic externalities, there is no agreement as to the precise way in which this occurs.

One point of view is that portrayed by Glaeser *et al.* (1992). Their study considers those factors that influence the innovative activities in urban regions, and identifies two different models in the economics literature. The so-called *Marshall-Arrow-Romer* model formalises the insight that the concentration of a particular *industry* within a specific urban region, i.e. industry localisation (Lösch, 1954), promotes intra-regional knowledge spillovers across firms and therefore stimulates innovation in the actual urban industry. The basic assumption here is that knowledge spillovers mainly take place across firms within the same industry.

An alternative view regards inter-industry spillovers as the most important source of new economically valuable knowledge. Specifically, Jacobs (1969) argues that the agglomeration of firms in urban regions fosters innovations, due to the diversity of the knowledge sources located in such regions. Thus, the variety of industries within an urban region can be a powerful engine of growth for that region, and the exchange of complementary knowledge across diverse firms and economic agents leads to increasing returns to new economically valuable knowledge.

An intriguing suggestion is presented in a study by Capello (2002). In her terminology the *Marshall-Arrow-Romer* (MAR) model refers to localisation economies, whereas the *Jacobs* hypothesis refers urbanisation economies. With these distinctions she finds for the Milano region that certain high-tech industries tend to be located in Milano rather than in smaller regions. However, she takes one further step and subdivides the Milano region into sub regions (zones). When doing this, the high-tech industries are in fact clustered in particular zones. Hence, the large urban region may provide certain variety advantages, but the location of firms reveals that there are fundamental localisation economies operating at the same time.

A related controversy has to do with the influence of market structure on R&D behaviour. The MAR tradition recognises that local competition may negatively influence the ability of firms to appropriate the economic value accruing from their innovative activity. At the same the MAR model assumes that it is primarily knowledge spillovers between firms in the same industry that stimulate innovation activities. In this sense Jacobs (1969) provides a contrasting picture by assuming that it is rather spillovers between industries that are important innovation triggers. As a consequence firms are less concerned about knowledge leakages, although appropriability may remain an important issue. Porter (1990) offers quite an apart description. He assumes that competition is more conducive to innovative activity, due to knowledge externalities.[5]

Since the early 1980s, several authors have provided an analytical framework relating market structure under oligopolistic competition to the nature of inventive activities (Dasgupta & Stiglitz, 1980; Kamien & Schwartz, 1982). These authors argue that both the market structure and the nature of innovative activities are endogenous, as they both depend on factors such as R&D, technology, demand conditions and the nature of capital markets. However, they generally assume that knowledge is monopolised by the firm that produces it, which means that the results of R&D activities are fully appropriable, thus disregarding knowledge spillovers. Although these models paved the way for investigations of the relationship between market structure and R&D intensity, the lack of an explicit spatial dimension makes it impossible to use these contributions as a set-up for the analysis of the geographic features of spillovers and their consequences. However, Kobayashi (1995) provides an analytical framework relating market structure to knowledge accessibility in knowledge networks. Further work along Kobayashi's ideas would indeed improve the understanding of the conflict arena.

5.2 University Knowledge Transfers

A major point in the endogenous growth theory is that knowledge is generated by economic agents and is hence an endogenous part of the economic process. In this setting newly generated knowledge spills over to other agents, thereby contributing effectively to the overall economic growth. In general, the complex (Beckmann, 1994), tacit (Polanyi, 1966) or sticky (von Hippel, 1994) nature of knowledge limits spillovers mainly to human interactions and contacts, which implies that knowledge spillovers and knowledge exchange are localised and bounded by spatial proximity. One might say that complex knowledge flows need short distances and require that sender and receiver are calibrated. The major provider of new scientific and technological knowledge is (research) universities. This suggests that to understand the functioning of regional innovation networks it is necessary to understand the knowledge links between universities and industry at various spatial levels.

Relationships between universities and industry received increased attention among researchers in the 1980s, particularly in the U.S. There were several reasons behind this new focus including the emergence of rapidly growing clusters of high-technology industries. Not least the emergence of dynamically expanding science-based technological fields such as microelectronics and biotechnology has increased the interest in the knowledge impacts of universities (Feller, 1989; Etzkowitz, 1998; McMillan, Narin & Deeds, 2000). A common denominator seemed to be a growing dependence on new knowledge and, in particular, knowledge generated by local university R&D. Universities – or rather research universities – were perceived as location factors of growing importance (Dorfman, 1983; Andersson 1985; Anderstig & Hårsman, 1986; Hall, 1987). It was suggested that regions with strong research universities would have much better opportunities to attract and support high technology industry than regions without such universities. Extending this idea, regionally based university research-

[5] It should be emphasised that the term "local competition" is used in Jacobs (1969) to denote competition for new ideas carried by the economic agents. This interpretation is at variance with that prevailing in the industrial organisation literature, whereby "local competition" is generally used to denote competition within product markets. An increased number of firms provide greater competition for new ideas, and greater competition across firms also facilitates the entry of new firms specialising in new, specific product niches. This is so because the necessary complementary inputs and services are likely to be available from small specialist niche firms but not necessarily from large, vertically integrated producers.

parks that institutionally integrated university and firm resources became a focal object of many studies (Luger & Goldstein, 1991). These beliefs were supported by the growing importance of network-type of innovation interactions among firms, and private and public research institutions (Lundvall, 1992, Ed.; Nelson, 1993, Ed.; Etzkowitz & Leydersdorff, 2000; Charles, 2003; Lawton Smith, 2003).

University knowledge transfer is defined as any process by which understanding, information and innovations move from a university to a firm in the private sector (Parker & Zilberman, 1993). The knowledge transfer between universities and industry may use many different links or mechanisms, as identified in Luger & Goldstein, (1991), Jensen & Thursby (1998), Siegel, Waldman & Link (2000), Adams, Chiang & Starkey (2000), Varga (2000), Shartinger & Rammer (2002), and Boucher, Conway & van der Meer (2003). These channels of knowledge flows include

- A flow of newly trained graduates from universities to industry
- Technological spillovers of newly created knowledge from universities to industry
- Industrial purchases of newly created university knowledge or intellectual property
- University researchers doing consultancy work for industry or serving at company boards
- University researchers leaving universities to work for industry
- University researchers creating new firms based upon their own research results, i.e. academic entrepreneurship[6] (Henrekson and Rosenberg, 2000).

The specific role played by each these different links for the development of industry are not well understood, since few studies go much beyond inferring innovation linkages from geographically coincident activities of universities and firms. Neither is there any consensus about how proximity can improve the functioning of these links (Karlsson & Manduchi, 2001). Furthermore, universities in many cases create incubators, enterprise centres and science parks to improve interaction with industry and to facilitate university knowledge transfers.

The actual links between universities and industry proved in many cases difficult to detect and proximity to fundamental research at universities sometimes failed to prove significant as an innovation factor (Markusen, Hall & Glasmeier, 1986; Malecki, 1991). However, recent and more sophisticated studies have shown strong evidence of knowledge transfers and spillover flows, as demonstrated by joint distributions of university capacity and high technology sectors (Varga, 1997 & 2002).

The literature presents a steady progression of methods and frameworks to investigate these relationships, beginning with a general knowledge production function that embodies broad forms of distance-sensitive knowledge flows, including tacit as well as formal knowledge inputs, moving to more precisely specified models of knowledge flows and spillovers through patents, patent citations and product innovations, particularly localized knowledge spillovers (LKS) (Varga, 2002). These studies of LKS occasionally, but not always, distinguish clearly between pecuniary and technological externalities, their various public and club good features, and various forms of private intellectual property. Mowery & Ziedonis (2001), for example, find knowledge flows from universities through market transactions to be more

[6] Slaughter & Leslie (1997) provide a comprehensive overview of the phenomenon in question.

geographically localised than those operating through non-market “spillovers”. This certainly indicates that the contact intensity is especially large when the knowledge has to be specified as a commodity for which the exchange of property rights is clearly defined.

Recent studies of knowledge transfers have tried to identify the channels by means of which knowledge can flow, and many of these studies build on the idea that knowledge is embedded in people. Therefore the mobility of knowledge workers is studied and how such workers embody the diffusion of knowledge as they move from one firm to another. Zucker, Darby & Armstrong (1988) were able to identify cases where market mechanisms, facilitated by the contracting of star scientists, induced transfer of knowledge from star scientists retaining their connections to universities while being affiliated to biotechnology firms. The localisation of biotechnology star scientists over the U.S. has been found to be an important factor in determining both the location and timing of entry of new biotechnology firms (Zucker, Darby & Brewer, 1998). Almeida & Kogut (1999) found that there are strong effects of the relocation of engineers in the semiconductor industry on the pattern of citation of patents, suggesting that movement of core individuals shape the evolution of industry. If knowledge is embedded in people, Møen (2000) suggests that we should be able to observe how wages reflect the accumulation of knowledge. In a study of technicians in the Norwegian machinery and equipment industry he found that R&D investments at least partially are incorporated in wages. In sum, these and other contributions indicate that the mobility of knowledge workers seems to be able to explain a lot of actual knowledge transfers – knowledge transfers that earlier were interpreted as more or less automatic knowledge spillovers.

5.3 Regional Innovation Networks

The development of innovations within regions is strongly influenced by the network of relations between firms and other economic actors, and the investments in such networks and is seen as a systemic feature with externalities, communication and interdependence playing crucial roles (Nelson, 1987; David, 1993; Antonelli, 1995). These regional innovation networks consist of a variety of inter-linked network configurations, such as suppliers’ or customers’ networks, regional networks to neighbouring firms, professional networks and knowledge networks, which all may contribute to a better innovative performance. A unique feature of these localised innovation networks is their embeddedness in a setting that also accommodates economic and social institutions (Araujo & Easton, 1996). The function of innovation networks seems to be intrinsically linked to what Hanssen-Baur & Snow (1996) refer to as the essential characteristics of a favourable learning environment, trust and shared language through purposeful interaction. The innovation capabilities inherent in each regional innovation network stem from the interplay between generic knowledge and learning processes (Antonelli, 1997). Such interplay is highly “localised” in that it is embedded in the technical and market environment of each individual functional region and in the experience of each innovator so as to be highly dependent upon its specific history. In this context the capability to innovate successfully appears to be conditioned by learning opportunities that are both internal and external to each economic agent. The architectural character of the regional innovation system, into which a firm is embedded, in terms of receptivity and connectivity shape the availability of information and communication channels among learning agents and firms, universities and research institutes so as to have a powerful effect on the innovative capability of each individual firm.

The character of the regional innovation networks implies that competition and innovation are increasingly undertaken simultaneously between firms involved in vertical and horizontal network relationships (Cox, Mowatt & Prevezer, 2003), sometimes under the direction of a leader firm (Carbonara, 2002). However, intra-regional competition and industrial diversity of the region also matters and the assumption here is that both competition and diversity foster innovation (Jacobs, 1969; Glaeser, et al., 1992; Feldman & Audretsch, 1999).

Innovation is a matter of applying entrepreneurial knowledge to transform inventions, i.e. technological knowledge, into economically useful products or processes with the intention to earn a rent (Schumpeter, 1934). Innovative activities involve an array of activities including interaction with users and suppliers resulting in innovations (Lundvall. 1992, Ed.). Innovation is a ubiquitous phenomenon. In all parts of modern functional regions, and at all times but to a varying degree there are ongoing processes of learning, searching, and exploring, which results in new products and new production processes including new forms of organisation and new markets. This implies that innovation is a gradual process with strong cumulative elements. Thus, future innovation is dependent upon the past, i.e. innovation is characterised by path-dependence. Much innovation may be regarded as a new use of pre-existing possibilities and components, i.e. most innovations reflect existing technological and entrepreneurial knowledge combined in new ways with perhaps no or very little new knowledge. The path-dependence of innovations indicates that the innovation systems in different functional regions will exhibit quite different development paths. Furthermore, a systems approach to innovation allows for the inclusion not only of economic factors influencing innovation but also of institutional, organisational, social and political factors. Thus, generically we should expect that the innovation system in each functional region will develop in its own idiosyncratic direction.

Since the market for many goods and services is limited to the regional market it is important to define an innovation as a good or a service that is new to the particular regional market. This implies that we can imagine a spatial process of innovation where a new good or service appears again and again as an innovation in different follower regions once it has first been introduced as an innovation in the leading region. This process may be driven by the original innovator who exports his innovation to other regions or who diffuses his innovation to other regions by means of direct investments or via franchising. It may also be driven by imitation by economic agents in follower regions, which introduces the original innovation or slightly changed versions of it in their own region. Which form the diffusion process will take will among other things depend upon to which extent the existing institutional framework makes it possible for the original innovator to appropriate the rents from his innovation. The spatial pattern of the diffusion process may either follow a hierarchical pattern ("filtering down diffusion") or a less predictable pattern ("spatial product life-cycle diffusion") (Karlsson, 1988). In the latter case the occurrence of new locations indicate the product is not new any longer, but the process may continue to be renewed (Johansson, 1998).

A serious limitation with the regional innovation networks approach is that it lacks an explanation for why certain innovations are initiated by new firms and not within existing firms. In the next section we provide such an explanation.

6. ENTREPRENEURIAL DYNAMICS IN THE SPATIAL KNOWLEDGE-BASED ECONOMY

To make this tentative model of the knowledge economy complete there are still two fundamental questions to answer. The first question concerns what drives the investments in R&D by firms to gain more technological knowledge? The natural answer is the expected profit. However, the institutional arrangements are important, since they determine the chances for firms to appropriate the benefits of the new technological knowledge they have created (Edquist, 1997; Carlsson, et al., 2002).

The second question concerns how entrepreneurs discover new business opportunities either by using new technological knowledge, i.e. a technological invention, or by combining existing technological knowledge in new ways, i.e. an entrepreneurial invention. On the one hand, existing and often larger firms engage in the search for and/or engage in the production of economically useful technological knowledge as input into their ongoing innovation processes. The possibility of turning localised knowledge into innovations depends on the capacity of existing firms in a region to appropriate existing learning opportunities by means of both R&D and internal learning, and also by the systematic absorption of the specific knowledge externalities available in the regional environment (Antonelli, 1998). This is stimulated in areas where monopolistic competition prevails, which makes it possible for innovative firms to earn a (temporary) monopoly profit. One might observe that small newly-created companies have certain market advantages as regards new technologies, since at early stages they tend to develop in low volume/high price niches that are less attractive for large firms (Stankiewicz, 1986).

6.1 Knowledge, Entrepreneurial Capacity and Entrepreneurial Initiatives

The explanation of the dynamics of entrepreneurial initiatives and the pertinent entry of firms traditionally relies on the combination of profit opportunities determined by the level of market concentration and structural entry barriers originating in the existence of scale economies and other cost advantages of established firms with respect to potential entrants (Bain, 1956). According to this tradition, innovative activities in the R&D laboratories of established firms are regarded as barriers to entry (Orr, 1974). Following Schumpeter's contribution, other authors more recently have stressed that innovation may represent a vehicle for new firms to successfully enter the market. Innovative entry is now widely regarded as a central force driving competition among firms (Dosi, et al., 1997). But since new firms by definition have done no R&D of their own (Acs & Audretsch, 1988), the theoretical framework must contain some mechanism through which new firms can get the innovation-creating inputs, i.e. the technological and entrepreneurial knowledge necessary for generating innovations.

The obvious mechanism is that old as well as new technological and entrepreneurial knowledge spills over for possible exploitation by other economic agents than those who created it. However, it is not obvious that economic agents which possess a mixture of technological and entrepreneurial knowledge that with a certain probability can be transformed into an innovation should appropriate the returns from that knowledge by becoming entrepreneurs. Of course, the potential innovation could be sold to an existing firm or to another potential entrepreneur. But the problem with asymmetric information (Akerlof, 1970) often implies that the best way to appropriate returns from such mixtures of technological and entrepreneurial knowledge is entrepreneurial action. Entrepreneurial initiatives or entrepreneurship generate an entrepreneurial act of organising resources to initiate commercial activity (Bhide, 1999).

It seems natural to assume that different economic agents have different endowments of technological and entrepreneurial knowledge and that it is exactly this uneven distribution of knowledge, which together with variations in regional market potentials and demand creates opportunities for discovering new goods and services, i.e. innovations. Of course, individual economic agents also differ in their capacity to discover, create and exploit innovations, i.e. to create new combinations out of existing technological and entrepreneurial knowledge, and thus to be organisers of change. One important reason to capacity differences among economic agents are differences in terms of integration in personal, social and professional networks (Birley, 1985; Aldrich & Zimmer, 1986; Szarka, 1990. Capacity differences are important since modern entrepreneurship is based on associated skills of a varied nature. An entrepreneur is an opportunity seeker, and in this endeavour he or she needs to have an eye for and a readiness to respond to an often rapidly changing external environment (Nijkamp, 2003).

Generally speaking two factors must converge for a nascent entrepreneur to found a new firm in a functional region, i.e. for an entrepreneurial event (Shapero, 1984) to occur (Sorensen, 2003):

- *Knowledge network*: The potential entrepreneur must perceive an opportunity for profit in a particular segment, or market niche, of the regional economy, i.e. have enough incentives to start a new firm. Since much of the relevant technological and entrepreneurial knowledge only exists privately, awareness of potentially profitable opportunities requires connections to those with the pertinent knowledge, typically those currently engaged in R&D in a particular field and/or those currently engaged in business in a particular industry. Entrepreneurs that can access the existing technological and empirical knowledge in the actual industry enjoy a large advantage (Klepper & Sleeper, 2002; Klepper, 2001).

- *Resource network*: The individual that perceives an opportunity must build a firm – assemble the necessary capital, skilled labour and knowledge – to exploit it. Social relations and networks play a crucial role in acquiring tacit knowledge and in convincing resource holders to join the new venture, whether as employees or investors. However, the wealth position of the individual (Lindh & Ohlsson, 1996 & 1998; Holtz-Eakin, Joulfaian & Rosen, 1994) as well as the supply of venture capital in the region (Malecki, 1997) also has important effects for the probability of he/she becoming an entrepreneur (and for the propensity to grow).

6.2 Entrepreneurial Opportunities in Large and Small Functional Regions

It is important to stress that there are strong spatial variations in entrepreneurial opportunities. These variations concern the institutional frameworks of functional regions, and their demand and supply conditions. Effective institutions bring down transactions cost, and thus the costs associated with establishing new firms. They also play a role in improving incentives, efficiency and rates of innovation, and in the definition and protection of property rights more generally. Variations in institutional framework between regions create variations as regards opportunities for knowledge flows and for appropriating rents from innovations. Regional variations in demand conditions in terms of regional market potential and regional demand for new goods and services generate spatial variations in entrepreneurial opportunities. There is also a strong variation between functional regions in the capacity of individual economic agents to discover, create and exploit innovations due to differences in educational achievements, work experiences, and so on. One can for example imagine that functional regions dominated by old declining industries, large scale manufacturing and/or large branch plants offer fewer opportunities to individual economic agents to develop innovations and thus creating a renewal process with path dependence.

The best opportunities for entrepreneurial initiatives are offered by functional regions with a large home market and a high access to markets in other regions, i.e. large functional urban regions. Entrepreneurs that make their start-ups in large functional regions may take advantage of close proximity to concentrations of their (potential) customers, i.e. of purchasing power, which, of course, could be other firms. Secondly, under certain conditions, entrepreneurs may take market shares from incumbents if they locate near them (Hotelling, 1929). Admittedly, this gain may be short-lived if further entrepreneurs enter, or if the incumbents in the region react to this unwanted competition. As a matter of fact, entrepreneurs may also suffer from the proximity of similar firms. Indeed, when competition in the product market is imperfect, geographical proximity increases competition in the product market (Fujita, Krugman & Venables, 1999). A third motive for entrepreneurs for locating in large functional regions may be more long-lived. Entrepreneurs may choose to locate in a large functional region because there they are more likely to be better exposed to customers. Searching is costly for the customer who *ceteris paribus* will prefer to minimize search cost by purchasing in areas of concentrated supply. This is particularly relevant in markets where potential customers are discerning with specific requirements, and wish to search before purchase. A fourth advantage of locating in large functional regions is the positive information externality in such regions, through which the individual firm receives signals about the strength of regional demand when observing established suppliers successful trades. Such observations also inform about varieties of existing goods and services and this can of course trigger the development of new varieties. Moreover, the fact that a given firm is located in a successful large functional region provides potential customers with an indication or image of quality. A fifth vantage for entrepreneurs to locate in large functional regions is risk reduction (cf. Mills & Hamilton, 1984). To the extent that fluctuations in demand are imperfectly correlated across customers, demand can be stabilised, since some customers are buying while other customers are not. Finally, when a firm finds a location in a large functional region, the firm can expect a local environment of qualified and demanding customers, which is important for entrepreneurs who are still in the process of developing their products.

Large functional regions also offer advantages to entrepreneurs in terms of knowledge flows that are particularly important when the knowledge is complex and perhaps tacit in nature (Jaffe, Trajtenberg & Henderson, 1993). Furthermore, they offer advantages in terms of access to a large pool of well-educated and specialised labour (Marshall, 1920) and of particularly specialised workers in accounting, law, advertising and different technical fields, which reduces costs of starting-up and expanding new businesses (cf., Krugman, 1993b). Furthermore, densely populated agglomerations are conducive to a greater provision of non-traded inputs, i.e., their service infrastructure is more developed. Such inputs are provided a both in greater variety and at lower cost (Krugman, 1991b, 1991c). There also exist physical infrastructure benefits for entrepreneurs of locating in large functional regions in terms of access to major highways and airports. Moreover, a form of informational externality accrues to new entrepreneurs from observing established firms producing successfully in a large functional region, i.e., there are large potentials for production knowledge to spillover in large regions. Thus, the start-up rate for each industry sector should increase with the existing density of establishments in each sector. A final reason for why large functional urban regions offer advantages to entrepreneurs arises from reductions in transaction costs (cf. Quigley, 1998). In particular, the search costs for customers, suppliers, services and knowledge are lower in larger regions. Economies of information flows (Acs, Audretsch & Feldman, 1992 & 1994) on both the demand and supply side are larger in large functional regions than in small ones. Thus, new firms are most likely to be started where such spillovers are greatest.

Generally speaking, the larger and richer the functional region, the larger the number of potential entrepreneurs, since the economic agents in such regions are better educated, have more varied work experiences, and so on. We may even assume that large and rich functional regions offer increasing returns in the acquisition of entrepreneurial skills due to more effective and more numerous interactions in denser areas (cf. Glaeser, 1999; Desmet, 2000). Such regions also offer favourable conditions for innovative entrepreneurship, as a result of a larger and more varied supply of skilled and educated labour, economics of density and the opportunities created by the large functional urban region as a nucleus of numerous networks with a spatial scale ranging from local to global (Nijkamp, 2003). Regional economic milieus which offer a rich supply of various types of networks, i.e., mainly large functional urban regions, tend to encourage entrepreneurial initiatives, since participation or involvement in regional or broader industrial networks makes it possible to externalise some of the risks involved (Shapero, 1984). This does not exclude the possibility that some smaller functional regions may offer favourable seed-bed conditions for entrepreneurship within, for example, specialised industrial clusters.

The implications of the above discussion are far-reaching. Since larger functional regions offer larger opportunities and higher capacity for entrepreneurial actions and a higher probability of successful entrepreneurial actions, these regions will experience a build up of entrepreneurial knowledge, which will stimulate further entrepreneurial actions. Furthermore, entrepreneurs are change agents who not only make decisions to start firms but who also shape local environments and institutions, and develop the resources and relationships that further their own interest as well as the interest of potential entrepreneurs through the creation of a positive local entrepreneurial environment (Feldman, 2001). The good conditions for entrepreneurial actions in large functional regions will stimulate potential entrepreneurs[7], often well-educated people, in smaller regions to move to larger regions since they offer better conditions for entrepreneurial actions. When more potential entrepreneurs gather in larger functional regions the conditions for entrepreneurship will improve due to an increased availability of entrepreneurial knowledge, which will induce further entrepreneurial initiatives and further in-migration of potential entrepreneurs from other (smaller) regions. In this sense entrepreneurial spatial behaviour is generating a dynamic cumulative concentration process.

However, the effects of entrepreneurial actions go much further. Entrepreneurs are involved in the introduction of new products and new processes in the market. Accordingly, they provide a major challenge to established firms and encourage them to improve their product quality and services or to reduce prices or to leave the market. This means that entrepreneurs play a fundamental role for the renewal of regional economies by strengthening competition and by initiating competitive processes that are the ultimate end results in a creative destruction of existing modes of production.

It must be stressed that start-ups and newly established firms face substantial risks for numerous reasons. As a consequence, the death rate among start-ups is relatively high but it tends to decrease rather rapidly over time. The survival or success rates of new entrepreneurs naturally show large variations between sectors and regions (Acs, 1994, Ed.). The regional economic milieu (including its culture, knowledge base and business attitude often appears to act as a critical success factor for new forms of entrepreneurship (Camagni, 1991). However, it is clear that successful new enterprises in a functional region contribute significantly to its economy and its employment but in particular to its renewal. All entrepreneurial start-ups can

[7] We use the concept potential entrepreneurs here to stress that when well-educated people move into larger regions from smaller regions the major attractor is probably the dynamic labour market in larger functional regions. However, as soon as the in-migrants are established in the larger region they become potential entrepreneurs that sometimes are better to discover business opportunities than people, which have lived for a long time in the larger region. However, it seems to be well-established that entrepreneurs rarely move when they establish new firms and in particular new high tech firms (Cooper & Folta, 2000).

be seen as experiments. All potential and active entrepreneurs benefit from learning the outcome of such experiments and the spillovers are proportional to the number of experiments. Since larger functional regions normally host more such experiments than smaller ones they also benefit proportionally more from such entrepreneurial learning and thus accumulate a larger stock of entrepreneurial knowledge over time, which implies that the externalities from entrepreneurial knowledge are dynamic in nature. In a multi-regional context, each functional region may build up a stock of regional entrepreneurial knowledge dependent upon current and past entrepreneurial activity (cf. Glaeser, et al., 1992), involving sets of "cumulative" experiments. Such regional accumulation of entrepreneurial knowledge affects the probability that entrepreneurial actions will take place and be successful.

What must be stressed here is that most entrepreneurial actions are constrained by the size of the regional market, because the market for most goods and services are limited to the regional market. Since the number of functional regions is large and since the market for many goods and services is even smaller than the regional market, the opportunities for entrepreneurial actions are very rich. Naturally the large functional urban regions offer the best general seed-bed conditions for the introduction of original innovations and for knowledge-based innovations in particular. However, the introduction of an original innovation in a large functional region is not the end of entrepreneurial activities. Instead it is the base for a series of subsequent entrepreneurial initiatives. In his strive to maximize profits the original entrepreneur will try to expand demand in the home region but also to supply other regions by means of export in a process of spatial innovation. In a parallel process, potential entrepreneurs in the home region but also in other regions will study the original innovation if it is significant and try to imitate it and doing so often also improve it. Thus, the introduction of original innovations will stimulate a competitive race, where the outcome will differ from innovation to innovation. In some cases the original innovator will be able to protect his innovation often due to a first mover advantage (Brown and Eisenhardt, 1998). In other cases the imitators will win. In still other cases both the innovator and the imitators will remain in the market, eventually creating a market structure characterised by oligopoly or monopolistic competition.

How far the entrepreneurial activities will spread spatially will depend on the demand conditions in different functional regions, and the geographical transaction costs and the internal scale economies associated with the specific original innovation. These factors will also determine whether a particular regional market with a large enough market potential will be served via import or local production. Swedish studies indicate that these secondary, imitation-like innovations in medium-sized and small functional regions are vital for the renewal of the economy in all these regions (RTK, 2003; Forslund 1998).

Entrepreneurial dynamics in the knowledge economy not only entail how economic agents establish new firms but also how entrepreneurial firms grow (Lechner & Dowling, 2003). The latter issue may be reformulated as the following question: how do entrepreneurial firms overcome growth barriers at different development stages? What incentives are needed to induce growth in entrepreneurial firms? We abstain from answering this question here but we maintain that the size of the regional market is an important factor for the growth of young entrepreneurial firms as well as their integration in various local and regional networks. As entrepreneurial firms mature, expansion to other markets outside the home market becomes critical. Thus, overall market access is a critical factor for the growth of maturing entrepreneurial firms.

The preceding discussion announces very strongly that large and rich functional regions are especially advantageous for entrepreneurial initiatives. How do then options of medium-sized and small functional regions look? According to Johansson & Karlsson (2001) such region may succeed in developing an economic milieu that can foster localisation economies in a minor set of industries. Such a milieu will then be the host of a limited set of specialised clusters or even single clusters. These may have many characteristics in common with entrepreneurial environments in large functional urban regions. However, one feature is special for the smaller functional regions. In order to succeed innovations in these regions have to be export-oriented from the very start. In other words, sales to markets outside the own region is the only means by which the innovative small functional regions can circumvent the limited size of the local market. Obviously, this constraint means that the profile of innovations in smaller functional regions is different and associated with links to customers in often distant and foreign markets.

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