The Regional Knowledge Economy; a Multilevel Perspective on Firm Performance and Localized Knowledge Externalities

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The Regional Knowledge Economy; a Multilevel Perspective on Firm Performance and Localized Knowledge Externalities

**De regionale kennisceconomie;
een multilevel perspectief op het presteren van bedrijven
en lokale kennisexternaliteiten**

(met een samenvatting in het Nederlands)

Proefschrift

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Acknowledgements

The spillover of knowledge is one of the central themes of this dissertation. One of the key premises is that "no single firm can have all of the required capabilities inside its corporate boundaries,"which stresses the importance of external knowledge sources and of leveraging knowledge flows in a network of relationships (see Chapter 1). In my opinion, this is especially true of this research project. I received tremendous support from my supervisors, colleagues, family and friends, almost always in the way of "knowledge transfers". I learned a great deal from their insights, capabilities and wisdom, and profited immensely from their (moral) support. This is a great opportunity to express my profound gratitude to the people who assisted me in writing this dissertation.

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1 Introduction; a multilevel perspective on firm performance and localized knowledge externalities

1.1 Introduction

In the emerging knowledge economy, the accumulation and transfer of knowledge are considered to be important for economic growth and performance. This stresses the value of internal knowledge-related firm capabilities, but also the existence of knowledge-based inter-firm relationships since critical resources may extend beyond firm boundaries. Although internal capabilities are considered to be a fundamental prerequisite, it can be argued that firms cannot rely solely on internal sourcing and also require external knowledge. As knowledge does not diffuse instantaneously around the world and to a large extent 'agglomerates', regional and geographical proximity have (re)emerged as important spatial units of economic activity. Regions, as collectors of knowledge externalities, contain traded and non-traded firm external knowledge-related circumstances that can induce firm performance, typically resulting from the presence and/or collective actions of other firms and institutions. When firms conduct internal and external knowledge acquisition activities simultaneously, they can complement their internal capabilities through a wide array of relationships with (nearby) external entities.

It follows that that, for a firm, being located in a region rich in knowledge resources is more conducive to economic performance than being located in a region that is less endowed with knowledge resources. Conceptually, the existence of contextual effects where firms are embedded in regions implies a multilevel problem in which firm-specific characteristics and relationships vary interactively with agglomerated knowledge circumstances. As several authors have argued that the underlying theory on externalities and agglomeration in principle is micro-economic in nature, this multilevel perspective fits an exciting new line of research focusing on the micro-foundations of regional economic development. This introductory chapter elaborates on this multilevel issue in regional economics and economic geography, outlines how this dissertation addresses it and discusses how we will empirically test micro-macro relationships in later chapters.

1.2 The rise of the knowledge economy

Although the pace may differ, all OECD economies are 'moving towards a knowledge based-economy', meaning that these economies 'are more directly based on the production, distribution and use of knowledge and information' (OECD 1996, 1999)[1]. One can argue that this rise of the

1 Drucker (1959) and Machlup (1962) can be considered to be among the first authors to introduce the term knowledge economy, claiming that 'knowledge is now becoming the one factor of production sidening both capital and labour'. Since the 1980s, one can speak of a revival of this claim, accompanied by different terminologies, like knowledge-based economy, weightless economy, information economy, new economy, learning economy, etc. Being aware of the nuances between these terms in general, the same general phenomenon is pointed to by each. We speak of (the rise of) the knowledge economy.

knowledge economy is the dominant post-industrial economic development paradigm that emerged in the 1980s. Knowledge creation and distribution are hypothesized to be primary drivers in the process of economic growth, the distribution of income and the growing importance of knowledge-based networks among firms, governments, and citizens (Harris 2001, Karlsson et al. 2005).

Of course, the role of knowledge in economic processes is constant, but its impact increases over time (Mokyr 2002). Smith (2002, p.8) describes this shift as follows: First, knowledge as an input factor becomes more significant both in quantitative and qualitative terms. This is, for example, reflected in growing levels of knowledge-related investment, such as in R&D, education, software and information technologies. Second, it is claimed that knowledge as a product is becoming increasingly important. This view rests on the observation that knowledge-intensive business services and high technology industries have grown dramatically over the years. Companies that belong to these sectors are often established on the basis of new ideas, incorporating and applying new knowledge into products. New forms of activity arise based on the trading of knowledge products. This is complemented by the growing importance of technological change in ICT since innovation in computing and communications changes both physical constraints and costs of the collection and dissemination of information. The rise of ICT technologies and the complex of ICT industries are arguably coterminous with the move to a knowledge society.

There are nuances to be highlighted in this appealing paradigm. David and Foray (2003), for example, argue that the transition to the knowledge economy in its most recent understanding is about a continuing transformation toward more knowledge-intensive activities rather than a radical change or rupture of economies and societies. The transition does not mean that more traditional drivers of economic development have become insignificant. For example, economies of scale and scope are still undoubtedly necessary for companies to compete, even in the new knowledge-based economy[2]. According to Venkatraman and Subramaniam (2001), the difference is in their significance. From being key drivers of distinctive competitive advantage in earlier eras, scale and scope have now become parity factors. While the benefits of scale and scope are necessary for companies to continue competing, they are no longer sufficient to create a distinctive advantage.

1.2.1 Knowledge in economic theory

A review of the recent economics literature dealing with knowledge suggests that several economic disciplines mark the importance of knowledge for economic functioning. According to Karlsson et al. (2005), a natural starting point for gaining a better theoretical understanding of the emerging knowledge economy is the new endogenous growth theory, formalized by Romer (1986) and Lucas (1988). Their critique of earlier approaches (especially that of Solow 1956), was not based on the

2 Economies of scale, internal to the firm, refer to the fact that the unit cost of production (beyond some minimum scale) is a decreasing function of output. Alternatively, this means that as a firm grows and production units increase, a company will have a better chance to decrease its costs. Economies of scope, internal to the firm, refer to the reduction of per-unit costs through the production of a wider variety of goods or services. This wider package makes it possible to spread certain fixed costs over a larger number of units. Similar to economies of scale, economies of scope provide firms with a means to generate operational efficiencies. We notice that the distinction between economies of scale, scope and 'knowledge' are not exclusive and overlapping (see Parr 2002 for a description of these terms and their mutual relationships).

basic model of the neoclassical production function, but rather what was perceived to be omitted from that model: knowledge. Romer, Lucas and others[3] argued that knowledge is an important factor of production along with the traditional factors of labor and capital and that because it is endogenously determined as a result of externalities and spillovers, it is particularly crucial (Audretsch et al. 2006). A main contribution of the new growth theory is therefore that it explains the causes of economic growth or, more precisely, technological progress (Audretsch et al. 2006). This theory emphasizes 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 forces behind economic growth. We refer to Grossman and Helpman (1991) for an extensive survey of what has been achieved in this field.

A second movement in the literature is that toward the knowledge-based view of the firm. There is a lively debate within the strategic management literature on 'the view of the firm' and how to fully cover the importance and role of knowledge in firms for achieving competitive advantage. Recently, this has been posed as the knowledge-based view of the firm (Grant 1996, Decarolis and Deeds 1999, Nonaka et al. 2000). This knowledge-based perspective considers knowledge to be the most strategically significant resource of the firm, and its proponents argue that heterogeneous knowledge bases and capabilities among firms are the main determinants of sustained competitive advantage and superior corporate performance. Contrary to earlier approaches,[4] the knowledge-based view of the firm does not treat knowledge as a generic resource rather than having special properties, but distinguishes different types of knowledge-based capabilities (Kaplan and Schenkel 2001).

A third new research strand that emphasizes the emerging role of knowledge for economic growth concerns the knowledge spillover theory of entrepreneurship (Acs et al. 2004, Audretsch et al. 2006). This theory suggests that, ceteris paribus, entrepreneurial activity will tend to be more prevalent in contexts where knowledge endowments are relatively high, as new firms will begin using uncommercialized knowledge spilled over from other firms and universities. The incomplete knowledge generated in incumbent organizations generates an entrepreneurial opportunity, and entrepreneurial activity in turn provides the conduit facilitating the spillover and commercialization of that knowledge. Entrepreneurial opportunity, in this theory, is no longer treated as exogenous and constant (Audretsch and Keilbach 2007).

These three theories - the endogenous growth theory, the knowledge-based view of the firm and the knowledge spillover theory of entrepreneurship - fit into the recent urgency to theorize and empirically test the hypothesis of the rise of the knowledge economy. In these theories, in addition to creation and production, the transfer (or distribution) of knowledge is especially central. Knowledge transfers and spillovers are considered key elements for firm-external economies (Henderson 2007, David and Foray 1995). Besides an organization's own ability to craft strong positions in its markets based on the strengths of its own processes, capabilities and routines, it

3 The work of Arrow in the early 1960s helped to shift the focus of neoclassical growth theory toward this treatment by considering knowledge that is derived from the experience of production with new capital goods, a process described as learning-by-doing (Arrow 1962, 1969).

4 For instance, the preceding approaches of the resource-based view or competence-based view of the firm.

is more frequently argued that firms can complement these internal capabilities with a wide array of external relationships. These so-called externalities[5] include traded and non-traded firm external circumstances that enhance firm performance, often beyond the control of the individual firm and typically resulting from the presence and/or collective action of other firms.

The theoretical notions in this section stress the value of knowledge-related firm internal capabilities, but also the existence of knowledge externalities. In the next section, we elaborate on the fact that these knowledge externalities to a large extent 'agglomerate', making the spatial dimension a potentially important unit of economic activity. The idea that both firm-specific characteristics and regional characteristics might matter is the overture to the argument that we are dealing with a multilevel problem (section 1.4).

1.3 Agglomerated knowledge

For externalities to occur in the knowledge economy, the question of how knowledge is transferred from one agent to another in the economic system is central. A burgeoning geographical literature stresses that the nature of knowledge implies that it cannot be easily transmitted across space and organizations, except in situations where agents or actors are proximate (Karlsson et al. 2005, Caniëls 1999[6]). In this literature, it is argued that there are reasons to believe that the generation of ideas and the results of ideas are locally bounded (Audretsch et al. 2006).

Theories stressing that knowledge externalities are spatially concentrated phenomena date back to at least Marshall (1890), elaborated later in what are called agglomeration economies. Knowledge externalities in particular received a lot of attention in this literature (Feldman 1999). Three types of agglomeration economies can occur as a result of the transfer of knowledge: a firm can learn from firms in the same industry (localization economies, often indicated as the MAR-externalities), from firms in other industries (Jacobs externalities), or from a concentration of actors other than firms, including consumers, universities, and governments (urbanization economies) (Van Oort 2004, Frenken et al. 2007). Studies by Glaeser et al. (1992), Duranton and Puga (2000), Feldman and Audretsch (1999), Henderson (2003) and Rosenthal and Strange (2003) have fueled the debate over how and to what extent these agglomeration economies foster economic growth. Related to these studies are studies on urban economics, analyzing human capital spillovers (Lucas 1988, Glaeser 1999, Glaeser and Maré 2000, Wheeler 2001), and studies with a specific focus on localized technological spillovers (starting with Griliches 1979, especially Jaffe 1989, Jaffe et al. 1993, Audretsch 2003 and Breschi and Lissoni 2009 stress the spatial dimension of technological spillovers).

5 In the literature, the phenomena of knowledge spillovers and knowledge externalities are often used as synonyms, without exactly defining what these terms mean and how they are related to each other. Several authors have recently stressed the importance of defining spillovers, and the context under which they occur, more precisely (as mainly non-traded or non-pecuniary; see Ponds 2008 for a recent overview of this debate, and Capello 2009 for a description of the variety of spatial spillover concepts). Taking notice of this debate in our study, we prefer to use the term externalities to denote both traded and non-traded firm external circumstances.

6 Caniëls (1999) described that these reasons stem from the nature of the innovative process, which can be summarized in five 'stylized facts' (see also Dosi 1988, Feldman 1994): uncertainty, complexity, reliance on basic research, importance of learning-by-doing and cumulativeness.

More geographical in nature, the 'territorial innovation' literature – elaborated in different concepts like clusters, industrial districts, regional innovation systems and learning regions – also has a strong tradition of analyzing how 'proximity' determines the transfer of knowledge (Markusen 1996, Cooke and Morgan 1998, Camagni 1991, Florida 1995). In this literature, arguments of face-to-face interaction, knowledge tacit-ness, the 'stickiness of information', trust-based relationships between firms, and spin-offs all point to advantages of regions and cities in explaining economic growth due to knowledge spillovers (McCann and Simonen 2005). This suggests that knowledge (and learning) processes especially take place at the local and regional levels, mainly due to the mechanisms that facilitate these externalities (Boschma and Frenken 2006): labor mobility, entrepreneurship and spin-off dynamics, and inter-organizational knowledge relationships (both formal and informal).

All conceptualizations conclude that knowledge does not diffuse instantaneously around the world (Döring and Schnellenbach 2006). As Glaeser et al. (1992, p. 1127) pointed out, knowledge spills over within a geographically bounded space because 'after all, intellectual breakthroughs must cross hallways and streets more easily than oceans and continents.' While the costs of transmitting information may be invariant to distance, the cost of transmitting knowledge rises with distance (Audretsch and Dohse 2007). Within regions, formal, traded and intended knowledge transfers are efficiently facilitated, but so are informal networking and untraded interdependencies (Geroski 1995, Dahl and Pedersen 2004, Storper 1997)[7]. Co-location is important because it provides a low-cost way for new ideas and talent to make their way into existing activities (Storper and Venables 2004).

In sum, this section discusses the fact that knowledge tends to agglomerate. The central argument stemming from the literature is that if knowledge transfers and externalities are important for growth, a firm's location influences its performance opportunities. In particular, when knowledge is not easily exchanged over longer distances and spills over locally, firms tend to agglomerate in order to capitalize on the knowledge stocks of neighboring firms and institutions. Agglomerated knowledge can be one of the main explanations for why regions differ in economic performance.

1.4 An intrinsic multilevel problem (macro and micro propositions)

Elaborating on the idea of agglomerated knowledge as externalities for firms, the empirical question is whether there are systematic differences in performance rates of firms engaged in the same industry across geographic space, but with different degrees of access to spatially bounded knowledge resources. This defines localized knowledge externalities for firms as a contextual research question. Firms interact with their geographically bounded context (Malmberg 1997). By conceptualizing knowledge externalities as contextual effects, it also becomes apparent that in order to gain a complete understanding, the various relevant levels of analysis need to be considered simultaneously (Duncan et al. 1998). We consider this a multilevel problem that concerns the relationships between variables that are measured at a number of different hierarchical levels (Hox 2002): here, 'the firm' (micro) and 'the region' (macro). Possible relationships in such research frameworks include macro variables influencing macro variables (relationship 1); micro

7 Dahl and Pedersen (2004) showed in their study that informal contacts are potentially an important source of knowledge. Even specific knowledge about new products, which is likely to be very firm-specific and which firms are likely to want to protect from competitors, is shared among knowledge workers.

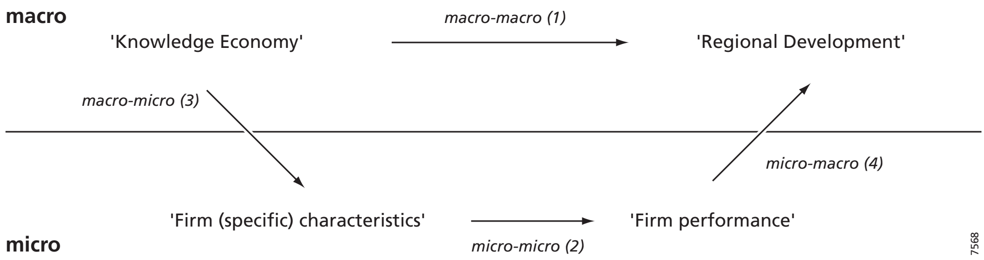

Figure 1.1 Macro-micro propositions

variables influencing micro variables (relationship 2); macro variables influencing micro variables (relationship 3), and vice versa (relationship 4); and often most interestingly, micro-micro relationships varying interactively with macro variables (interaction between relationship 3 and 2). Figure 1.1 shows the macro-micro (multilevel) propositions conceptually.

While section 1.2 in this chapter stressed the relationship between 'agglomerated knowledge' and 'regional economic development' (the macro-macro in figure 1.1), there is a burgeoning interest in the question of how variables at both the macro and micro levels simultaneously relate to individual-level firm performance. Since agglomeration economies are basically micro-economic in nature, the core of this dissertation therefore focuses on the need to:

> detect the effects of macro level characteristics such as 'agglomerated knowledge' on firm performance, in addition to firm-level characteristics (relationship macro-micro). One step further, it is also necessary to see whether macro characteristics influence the relationship between firm specific characteristics and firm performance. The latter can be characterized as a cross-level interaction effect between phenomena at the macro and the micro level.[8]

To accommodate analyses that test micro-macro and cross-level interactions, we need a firm-based framework that indicates whether firm heterogeneity can be related to regional factors that are not equally available to competitors located elsewhere. Box 1.1 elaborates on the arguments for inter-firm knowledge interaction and why firms can complement their internal capabilities with (nearby) external entities. These have to do with the fact that since the production of goods and services requires the combination of many different types of specialized knowledge efficiency, knowledge application depends upon the ability to integrate many different types of knowledge and on the ability to utilize knowledge to its full capacity. Next to acquiring knowledge, (the potential of) accessing the knowledge resources of other firms is also important.

8 An example of a firm-specific characteristic is firm size. One can argue that due to economies of scale, large firms have advantages compared to their smaller counterparts. Since large firms might be unequally distributed across regions, it is important to control for this firm-specific effect when determining the impact of the region. On the other hand, one can argue that the relationship between size and performance differs regionally due to the contextual circumstances. Possibly large firms need externalities less that small firms, and especially, small firms perform better when located in a region that is endowed with many knowledge sources.

To conceptualize the relationship between the knowledge economy (top left in figure 1.1) and firm characteristics and abilities (bottom left), the notion of absorptive capacity is often introduced. Firms need translating capacities to actually learn from external knowledge sources. Some researchers have argued that firms without any major internal competencies or valuable resources can survive and thrive if they are favorably located, just as the competitiveness of otherwise identical firms may diverge as a consequence of the way in which differences in location show up in their strategies (Maskell 2001). On the other hand, it is more often argued that internal knowledge sources and capabilities can be complemented by a wide array of relationships with external entities, but that they require a different set of internal strengths, both in terms of understanding where the potential sources of knowledge reside and the ability to absorb and deploy external knowledge. Cohen and Levinthal (1990) suggested that firms must develop an internal core knowledge base so that they can understand external knowledge and know how to apply it to their specific needs. The ability to identify, assimilate and apply for commercial purposes know-how generated outside one's own organization is considered to be one of the most relevant business characteristics in determining the productivity and innovativeness of firms.[9]

From the perspective of cross-level interaction, a vivid debate concerns entrepreneurship and new firm formation. Geroski (1995) argued that new firms' growth and survival prospects depend on their ability to learn from their environment and to link their strategic choices to the changing configuration of that environment. This is what Audretsch et al. (2006) noticed empirically for new firms: opportunities for entrepreneurship, and therefore for knowledge-based start-ups, are superior when they are able to access knowledge through geographic proximity to knowledge sources, such as universities. A new firm wanting to generate its own knowledge capital will be limited by scale and time. Instead, the use of external knowledge and ideas can leverage a firm's own knowledge capital by standing on the shoulders of giants.

The impact of 'agglomerated knowledge externalities' varies across firms within the same location and should not be treated as a location-specific externality for all firms in a region. According to Duncan et al. (1998), contextual effects may not be the same for all types of firms. As we have dealt with an intrinsic multilevel problem, this is not a simple empirical task. As Coleman (1986, p. 1323) said: 'it is this type of relation that has proved a main intellectual hurdle both from empirical research and for theory that treats macro-level relations via methodological individualism'. The multilevel perspective provides us with better insight into 'if, and how the region' matters since regional variations in economic development can be observed for a number of reasons, some of which may be due to characteristics of the areas and others that relate to the characteristics of the firms and economic activities in these areas. Macro-macro relationships indicate that the rise of the knowledge economy fosters regional development (for instance, in urban agglomerations or innovative clusters). Micro-micro relationships indicate the importance of the integration of knowledge in the organization of the firm, eventually resulting in better firm performance. In this dissertation we focus on the macro-micro and micro-macro (multilevel) relationships, the

9 Linked to the concept of absorptive capacity, the importance of face-to-face contacts is stressed (Glaeser 1999, McCann and Simonen 2005). In particular, the information used by innovators has a tacit component: information that is difficult to set down in blueprints or to codify completely and hence is difficult to communicate at a distance. Face-to-face interaction facilitates the transfer of knowledge and can condition a firm's absorptive capacity.

importance of (spatially bounded) knowledge externalities for firm performance and the way performing firms, responding to the adaptation of knowledge, are the drivers for regional economic development.

In chapter 2, we will elaborate on our multilevel analysis. We now turn to the aim of our study and research questions.

1.5 Aim of the study and research questions

We started with the phenomenon of the rise of the knowledge economy as a source for economic growth. Since knowledge agglomerates, it can foster regional economic development (explaining the unequal distribution of economic development in space). This suggests that being located in a region rich in knowledge resources is more conducive to firm performance than being located in a region that is less endowed with knowledge resources. Traditionally, 'macro studies' (meaning spatial or geographical) using spatially aggregated data with cities or city-industries as the basic reference unit have convincingly shown a positive correlation between geographical clustering, the agglomeration of knowledge and regional performance (in terms of productivity, economic growth or innovations). Over the years, a large body of literature has provided us with insight into why some regions grow faster than others and how interactions between increasing returns to scale, scope and expertise of firms and geographic location lead to a particular distribution and development of economic activities. Focusing on this 'economic value of location' (as a mechanism for accessing external knowledge resources, which in turn manifests itself in higher rates of performance), it is rightly claimed that the theories that underlie externalities are microeconomic in essence (Rosenthal and Strange 2004, Duranton and Puga 2004). This would imply that the relationship between spatially bounded externalities and economic performance should actually and most profoundly hold at the micro or firm levels (Audretsch et al. 2006, Beugelsdijk 2007). Within the localized externalities debate, however, 'the firm' as research object is not much taken into account (Malmberg 1997, Taylor and Asheim 2001, Audretsch and Dohse 2007)[10]. The aim of our research is to both conceptually and empirically contribute to the understanding of the effects of agglomerated knowledge circumstances on firm performance. At the conceptual level, as described in this chapter, we consider this an intrinsic multilevel issue containing different kinds of macro-micro relationships. We test empirically some of the underlying assumptions by estimating random effects or multilevel models, using data at the establishment level simultaneously with agglomerated knowledge variables.

Although the transfer of knowledge is the central focus in theorizing spatially bounded externalities, the aim of our research is not to test different types of inter-firm knowledge flows. We

10 This omission can be problematic since information on the existent variance between firms is crucial for understanding divergent development trajectories of firms and regions. In addition, agglomeration effects found in area-based studies may be compositional, following from spatial selection processes. Although several firm-level studies that include the role of the region have been conducted over the last few decades (see, for example, Sternberg and Arndt 2001, Fritsch 2004, Knoben 2008), such studies remain relatively scarce. These studies mostly focus on the innovative performance of firms and not their productivity or employment growth. One of the few exceptions that focuses on economic performance is the study by Audretsch and Dohse (2007).

will also not focus on the exact aspects of firm learning and absorptive capacity. The central question is a more basic one:

> How are localized knowledge sources mutually and simultaneously related to economic growth processes at the regional and firm levels?

Taking figure 1.1 as a guideline, we want to answer the questions of how the availability of localized knowledge sources impacts firm performance (a macro-micro relationship combined with a micro-micro) and how firm-level growth in turn relates to regional economic development (a micro-macro relationship). As we argued that this central question is an intrinsically multilevel one, our main contribution is that we empirically test it with a multilevel approach, simultaneously taking firm-specific and regional characteristics into account and especially focusing on the interaction between these two. Contextual effects may be too complex to reduce to overall summary measures, and at the same time, the differences between firms' performance may be too complex to reduce to simple summary 'averages' (Duncan et al. 1998). Nuances in the interaction between the firm and its geographical context need to be accounted for. This requirement poses technical difficulties for traditional statistical modeling techniques as they generally operate at a single level. In chapter 2, we will argue that multilevel models can provide a comprehensive framework to empirically address the key contextual considerations of the firm located in a region.

In chapter 3 we first take a macro-macro approach, in line with many regional science studies. Focusing on the spatial consequences of the knowledge economy, we explore the unequal distribution of knowledge sources (activities) and knowledge-related explanations for why some regions grow faster than others. Then, chapters 4, 5, 6 and 7 employ a firm-level approach, investigating whether localized knowledge externalities can be related to performance differences between firms. We pay explicit attention to the fact that these relationships might vary according to geographical context and that certain firm-specific factors can precondition this interaction.

The different chapters elaborate on these firm-specific characteristics. We take an eclectic approach as some of the characteristics specific to the firm stem from the industrial organization literature, like size, age, and industry (such as high tech versus low tech sectors), and others from the strategic management science literature, like a firm's absorptive capacity, and transfer mechanisms related to inter-firm interaction, like the use of ICT and the amount of face-to-face interaction.

From a theoretical point of view, the literature stresses the importance of new firms, suggesting that entrepreneurship is the missing link between investments in knowledge and economic growth (Audretsch and Lehman 2005a). Acs and Plummer (2005) argued that new firms matter more than incumbent firms in allowing knowledge spillovers to contribute to economic growth. Therefore, we pay special attention to new firms.

1.6 Outline of the research

The study consists of eight chapters. Figure 1.2 indicates the research questions addressed in each chapter. Chapter 2 will elucidate the advantages of multilevel analysis and models for the micro-macro research question of knowledge externalities. Chapter 3 presents the spatial knowledge

Box 1.1 The knowledge-based view of the firm

As indicated, the aim of this dissertation is conceptual and empirical. Theoretically, focusing on 'the firm' in its regional context, one can say that knowledge-based thinking is still in its early stages (Eisenhardt and Santos 2000, Malmberg 1997, Taylor and Asheim 2001). In this box, though we elaborate on the several theoretical arguments offered by 'the knowledge-based view of the firm', mainly to show that this perspective offers a number of useful insights into the multilevel issue, we want to explore the identification of and access to relevant knowledge that is created in the environment as one of the fundamental aspects of the knowledge economy (Grant 1996).

The knowledge-based view of the firm considers knowledge as the most strategically significant resource of the firm, and its proponents argue that heterogeneous knowledge bases and capabilities among firms are the main determinants of sustained competitive advantage and superior corporate performance. Processes through which knowledge is sourced, transferred, and integrated within and across organizations are at the heart of their argument (Eisenhardt and Santos 2000). As said, our magnifying glass is not on the firm internal processes as such, but on interaction with external knowledge sources.

Within the knowledge-based perspective, knowledge-based capabilities are considered to be the most strategically significant resource of the firm and form the main determinants of sustained competitive advantage and superior performance. Firms strive to make their capabilities valuable, rare, inimitable, and non-substitutable in order to protect their sources of competitive advantage against resource imitation, transfer, or substitution. Starting from this perspective, it seems unsound to assume that spillovers are virtually automatic, costless and unconstrained, as in the arguments of 'public good properties' (knowledge is non-rival and non-excludable: the same idea can be used in different applications and in different locations at the same time, and the originators of an idea may have difficulty extracting compensation from all agents that make use of it).

More and more, though, it is argued that there are potentially beneficial factors that are not (completely) internal to the individual firm but (also) lie outside its boundaries. Arguments of collective learning (Foss 1999) and learning-by-interacting (Lundvall 1992) have come to the fore as externalities that inhabit intangible aspects of knowledge sharing. The social complexity, tacitness or presence of causal ambiguity bind interacting firms together. Interaction between firms is considered to be fostered by trust-based relationships, frequent contacts and face-to-face interaction.

Grant and Baden-Fuller (2004) go further by positing that interfirm relationships (especially strategic alliances) are not only driven by motives of acquiring knowledge (the learning motives), but also by accessing the knowledge resources of other firms. The first motive can tend to converge as each partner learns from the other (due to 'competition for learning': a firm seeks to learn at a faster rate than its partner in order to achieve a positive balance of trade in knowledge). The second motive stresses that partners in inter-firm relationships will maintain and possibly increase their knowledge specialization. According to Grant and Baden-Fuller (2004), knowledge accessing (called 'exploitation' by March (1991) and 'knowledge application' by Spender (1996)) provides the predominant motive for inter-firm alliances. Such alliances are based on activities that deploy existing knowledge to create value, mainly to exploit complementarities, but with the intention of maintaining each firm's distinctive base of specialized knowledge.

Grant's argument is built up by characterizing knowledge (1) as the overwhelmingly important productive resource in terms of market value, (2) as varying in its transferability, (3) as subject to economies of scale and scope[11], (4) as created by individual human beings (and to be efficient in knowledge creation and storage, individuals need to specialize), and finally (5) by indicating that producing a good or service typically requires the application of many types of knowledge. Starting from these premises, he argues that in particular, the fundamental dichotomy between knowledge creation (exploration) and knowledge application (exploitation) becomes clear: knowledge creation requires specialization (points 3 and 4 above), while knowledge application requires diversity of knowledge (point 5). Given the limited transferability of knowledge (point 2), this presents considerable difficulty for the institutions of production. According to Grant (2004), the solution lies in some process of knowledge integration that permits individuals to apply their specialized knowledge to the production of goods and services while preserving the efficiencies of specialization in knowledge acquisition. He argues that if we focus upon knowledge application, the question is: what factors determine the efficiency with which knowledge assets are transformed into goods and services? If production requires the combination of many different types of specialized knowledge (point 5), each of which is subject to economies of scale and scope (point 3), then efficiency in knowledge application depends upon, first, the ability to integrate many different types of knowledge and, second, the ability to utilize knowledge to its full capacity (Grant 2004).

From a knowledge accessing and integration perspective, inter-firm relationships are logical extensions of the firms' boundaries since products and services require a broad range of different knowledge types (and efficiency of integration is maximized through separate firms specializing in different areas of knowledge and linked by inter-firm relationships). Input-output relationships between knowledge and products are not static but dynamic: knowledge is continually being created, refined, discarded, and reconfigured into new products. If a firm is uncertain as to the future knowledge requirements of its current products and if acquiring and integrating new knowledge takes time, its knowledge investments are risky. The greater the uncertainty as to the future knowledge requirements

11 Grant and Baden-Fuller (2004): Since the costs of replicating knowledge tend to be lower than the costs of the original discovery or creation of the knowledge, knowledge is subject to economies of scale. To the extent that knowledge is not specific to the production of a single product, economies of scale imply economies of scope. The extent of economies of scale and scope varies considerably between different types of knowledge. They are especially great for explicit knowledge, information in particular, which is costly to produce, but cheap to reproduce. Tacit knowledge tends to be costly to replicate, but these costs are lower than those incurred in its original creation.

of a firm's product range, the greater its propensity to engage in inter-firm collaborations as a means of accessing and integrating additional knowledge. Additionally, where knowledge is advancing rapidly, appropriating its returns often depends upon achieving an early-mover advantage. If an early-mover advantage rests upon the ability to quickly identify, access, and integrate across new knowledge combinations, inter-firm relationships can greatly increase the speed with which a company can access the new combinations of knowledge needed to bring new products to market. Grant and Baden-Fuller (2004) conclude that the advantages of inter-firm relationships are especially apparent under conditions of uncertainty and early-mover advantages.

In short, one can say that the key premise is that no one firm can have all of the required capabilities inside its corporate boundaries, which emphasizes the importance of knowledge externalities and of leveraging knowledge flows in a complex network of relationships. Multilevel approaches (called interactionist or system dynamic in the management science literature; see Short et al. (2007)) that include the interaction between firm internal and external knowledge-related processes are stressed as important. Here, special attention should be paid to the relationship between knowledge sourcing and firm performance. Eisenhardt and Santos (2000) claimed that only a few studies have examined firm performance in relation to knowledge transfers, and that there is much to be gained from this field of research.

economy in the Netherlands, showing spatial patterns at a low spatial scale and drawing a conclusion on the relationship between local knowledge and economic growth. Chapter 4 links these spatial knowledge patterns to micro data of survival and (employment) growth of firms. An OLS estimation framework is used. This chapter discusses the impact of localized knowledge externalities on firm growth. Chapter 5 shows the added value of the use of multilevel modeling compared to the use of OLS modeling. This chapter presents conclusions concerning the need to control for firm-level heterogeneity and the potential of cross-level interaction variables. For this research, we constructed a firm-level database based on a survey in which we gathered information on individual productivity. Chapter 6 elaborates on this research and relates multilevel modeling to the debate of the 'learning region' and firm internal transitions from economies of scale, to scope, to expertise. This chapter concludes on firm internal economies of expertise (like absorptive capacity and transfer mechanisms) and their interaction with localized knowledge externalities. Chapter 7 focuses on survival and employment growth of new firms since the literature suggests that entrepreneurship particularly facilitates geographical knowledge spillovers.

Chapter 1
Introduction. A multilevel perspective on firm performance and localized knowledge externalities

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Chapter 2
The firm and spatially bounded knowledge externalities: multilevel analysis and modeling

Chapter 3 (macro-macro)
The knowledge economy and urban economic growth:
Which aspects of the knowledge economy are discussed in the literature as important for (regional) economic growth, and can a relationship between these aspects and economic growth on the regional level be found?

Chapter 4 (macro-micro, contextual)
Firm growth and localized knowledge externalities:
Can firm growth be related to spatial differences in knowledge intensities while simultaneously taking relevant firm-level characteristics into account?

Chapter 5 (macro-micro, multilevel)
Firm heterogeneity, productivity and spatially bounded knowledge externalities:
Does multilevel analysis, taking the hierarchical structure of the firm in the region into account, give a better insight into the (knowledge) effect of the region on firm performance?

Chapter 6 (macro-micro, multilevel)
Firm performance in knowledge regions:
Do firms profit from their higher order spatial (knowledge) context, and if so, vary these relationships according to geographical contexts and precondition certain knowledge-related firm internal factors on this interaction?

Chapter 7 (macro-micro, multilevel)
Growth of new firms and spatially bounded knowledge externalities:
Will new firms, triggered by and using external knowledge inputs, exhibit superior performance when located in knowledge rich contexts?

Chapter 8 (macro-micro, multilevel)
Conclusions

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Figure 1.2 Outline of the research

2 Multilevel analysis and modeling

'Once you know that hierarchy exists, you see them everywhere'
(Kreft & De Leeuw, 2004, p.1).

2.1 Introduction

In the previous chapter, we argued that the phenomenon of spatially bounded knowledge externalities is an intrinsically multilevel problem. Starting from this, in this chapter we introduce a multilevel research framework necessary for analyzing this problem. We show the advantages of multilevel modeling, the method we will use in the empirical chapters of this dissertation. The applicability of such a multilevel approach in our research is related to the issue of 'context or composition' - to analyze whether observed differences between places are genuine or merely an artifact of within-place characteristics, that is, the composition of a place (Jones 1997). As indicated in chapter 1, this also concerns the issue that the relationship between region-based characteristics and economic development (e.g. firm growth) may systematically differ across certain contexts. In this chapter, we introduce multilevel analysis as an effective way to deal with these multilayered research issues.

2.2 The individual-context dilemma in empirical analysis

Previously, researchers studying spatially bounded knowledge spillovers and externalities were on the horns of a dilemma[12]. They had to work at either the level of the aggregate (as adopted by many geographers) or of the individual (the preferred choice of many firm-level scientists). Choosing to work at the aggregate level makes one's work vulnerable to the charge of the *ecological fallacy*, while choosing to work at the firm level risks being found guilty of *atomistic fallacies*.

Ecological fallacies occur when the argument that 'the region matters' seems to be deduced from a macro-level phenomenon of, for example, agglomerated knowledge externalities, but is used as micro-level 'evidence'. A correlation found at the regional level does not necessarily mean the same thing as a correlation at the individual level[13]. In the literature, this is also known as the 'Robinson effect' after Robinson (1950), which gives an interpretation of aggregated data at the individual level. If the analyst is not very careful in the interpretation of the results, s/he may commit the fallacy

12 Analogy based on Jones (1997)

13 Robinson presented aggregated data describing the relationship between the percentage of black people and the illiteracy level in nine geographic regions in 1930. The ecological correlation (correlation between aggregated variables) at the regional level is 0.95, but the individual correlation between the absolute variables at the individual level is 0.20. Robinson concluded that in practice, an ecological correlation is almost certainly not equal to its corresponding individual correlation (Hox 2002).

of the wrong level, which consists of analyzing the data at one level and drawing conclusions at another level.

In the economic geographical literature, the fact that evidence stemming from spatial analyses does not necessarily mean that spatial 'contextual' effects have significance for individual firm performance, is also indicated as a type of *'endogeneity'* problem. In short, agglomeration economies, like knowledge externalities, are assumed to enhance firm performance, but successful entrepreneurs also seek out high performance (productive) locations. If overachieving entrepreneurs were disproportionately found in agglomerated areas, this would cause one to overestimate the relationship between agglomeration and output (Rosenthal and Strange 2003). Not only is the economic output (growth or productivity) in a given area sensitive to the composition of firms in the area (an agglomeration effect), but the reverse may hold as well.

Such endogeneity problems indicate the need to control for firm heterogeneity, which determines the regional composition, while determining the isolated impact of location (Brakman and Garretsen 2006, Koo and Lall 2007, Mariani 2004). Not controlling for this firm-level heterogeneity creates the danger of wrongfully assigning an impact to 'regions'. Regional analyses therefore potentially overestimate the importance of external economies (Baldwin and Okubo 2006).

Working at the micro level while simultaneously including external variables might be a solution to overcome ecological fallacy problems. However, this also faces difficulties. Choosing to work at the individual levels may lead to *atomistic fallacies* (Alker 1969): the problem of disaggregation of contextual variables, linking the value of a variable at the regional (or higher) level to all units at the lower level to which they belong, which 'blows up' the regional values because information from fewer regional units is treated as if it were independent data for the many units at the micro level. This atomistic fallacy (conceptually the reciprocal of the ecological fallacy) rests on the issue that there is no necessary correspondence between individual-level and group-level relationships. This might lead to errors in sample size treatment, providing over-optimistic estimates of significance and correlated errors of firms belonging to the same context, which violates one of the basic assumptions of multiple regression analysis (Hox 2002). This approach assumes that the regression coefficients are equal in all contexts, thus propagating the notion that processes work out in the same way in different contexts. In short, a single level approach misses the context in which firm behavior and performance occurs.

2.3 Multilevel analysis in a geographical context

Standard statistical approaches to aggregate and disaggregate analysis cannot deal with both ecological and atomistic fallacy-dangers because they operate at a single level (Hox 2002). Multilevel models were explicitly developed to resolve this dilemma by working at more than one level simultaneously, so that an overall model can handle the micro-scale of firms and the macro-scale of places. Multilevel analysis, though, is not very common in economic geographical studies, but is the norm in the social, medical and biological sciences (Rasbash et al 2005[14]). We suggest that in economic geography and regional economics, this method can cope with some of the research issues that are priorities to resolve (Dicken and Malberg 2001).

2.3.1 Hierarchical data

Traditionally, multilevel analysis is used to better account for the existence of hierarchical structures in the research population. According to our research question, the general concept is that firms interact with the context in which they operate, meaning that firms are influenced by this context and that the firms that make up a context in turn influence the properties of this context. When, in the case of knowledge externalities, this context is spatially bounded, one can argue that firms in regions are conceptualized as a hierarchical system. Therefore, the data structure is also hierarchical: the population consists of regions and firms within these regions (also called *nested* structures). In such samples, the individual observations are in general not completely independent. For instance, firms in the same region or location tend to be similar because of selection processes[15]. As a result, the average correlation between variables measured in firms from the same region will be higher than the average correlation between variables measured on firms in different regions. Standard statistical tests lean heavily on the assumption of independence of the observations. If this assumption is violated, the estimates of the standard errors of conventional statistical tests are much too small, and this results in many spuriously 'significant' results (Hox 2002). This is better known as the *Moulton* problem (Moulton 1990).

2.3.2 Between place variance

One of the basic underlying problems related to using regions as units of analysis is that one is not able to assess the relative importance of the region at the macro level (Goldstein 2003, Moon et al. 2005). This leads to a plea for decomposing the variance and distinguishing regional differences from the difference that 'the region' makes. Such an approach to examining regional variations in economic development, consequently, entails describing the patterning and causes in economic development variations, which in turn requires answering the following empirical questions, preferably in a sequential manner:

First, how is the total variation in economic development partitioned across the individual and area levels? Second, how much of the variation in economic development that is attributable to areas is influenced by the characteristics of individual residents who live in these areas? Third, to what extent do region-based characteristics account for the region-attributable variation in economic development? Fourth, what is the systematic relationship between region-based characteristics and economic development, and does this relationship systematically differ across different contexts or population sub-groups (cross-level interactions)?

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14 For example, school education provides a clear case of a system in which individuals are subject to the influences of grouping. Pupils or students learn in classes; classes are taught within schools; and schools may be administered by local authorities or school boards. Thus, if we are measuring educational achievement, it is known that average achievement varies from one school to another. This means that students within a school will be more alike, on average, than students from different schools. Likewise, people within a household will tend to share similar attitudes, etc., so that studies of, say, voting intention need to recognize this. In medicine it is known that centers differ in terms of patient care, case mix, etc., and again, our analysis should recognize this. For an overview study on the effect of the school on pupil outcomes based on a review of multilevel studies, see Sellström and Bremberg (2006). For an application of multilevel studies in public health studies, see Duncan et al. (1998) and Diez-Roux (2000). For an applications of multilevel studies in sociological health studies, see DiPrete and Forristal (1994).

15 This is what we earlier mentioned as the 'endogeneity' problem: regions may attract firms with certain specific characteristics.

The basic concept underlying multilevel modeling is the simultaneous specification of models at each level. More specifically, there is an individual-level micro model that represents the within-place equation and an ecological macro-model in which the parameters of the within-place model are the responses in the between-places model. Thus, multilevel models 'decompose' the total variance into 'within-place' and between-place' components. The latter, the covariation between firm performances sharing the same regional externalities, can be expressed by the *intra-class* correlation (Hox 2002). With intra-class correlation, the between-regions variance contributes to individual firm growth, in addition to the between-firm growth variance.[16]

2.3.3 Random intercepts and slopes

Multilevel analysis is an improvement over other analysis in that the sampling design better fits the possible causes of dependency in the data. The advantage of the multilevel structure is the allowance for 'contextual' effects *within* firm-specific relationships. The reasons for this are twofold (see box 2 for an extended elaboration). First: some places have uniformly higher rates of firm performance than others, and *second*: place can make a difference for certain types of firms. A particular strength of the multilevel approach is that higher-level units such as regions remain in the analysis as identifiable entities.

Box 2 Random intercepts and slopes

To visualize the basic concept of multilevel analysis, a two-level model is shown, considering two variables with firms at level 1 and regions at level 2. The response variable is firm performance, and the individual predictor variable is a firm-specific variable: for this example, firm size. Figure 2.1 gives a range of possible models. In 2.1(a), the general relationship is shown as a straight line with a positive slope: the larger the firm, the better its performance (the general idea of internal economies of scale). In this graph, there is no context: place does not matter for economic performance, which is only conceived in terms of firm-specific characteristics. This is 'remedied' in 2.1(b), with each of the different places having its own relationship represented by a separate line at a varying 'distance' from the general underlying relationship shown by the thicker line. The parallel lines imply that, while the performance-size relationship in each constituency is the same, some places have uniformly higher rates of economic outcomes than others. This model allows for random intercepts. The situation becomes more complicated in 2.1(c) to 2.1(f) as the steepness of the lines varies from place to place, visualizing the allowance of random slopes. In 1(c), the pattern is such that place makes no difference for small firms, but places have very different outcomes for large firms. In contrast, 2.1(d) shows relatively large place-specific differentials in economic outcomes for the small firms. This latter, for example, fits the underlying hypothesis that small firms due to their lesser abilities to invest in research and development activities, profit more in some regions than in others, specifically more in regions that are

16 When ordinary significance tests are used (like in linear multivariate regressions), treating the individual as the unit of analysis, the important assumption of independence of residual error terms is violated, potentially leading to too liberal significance levels (Barcokowski 1981). Random effects models were developed for this cause and solve these kinds of problems (Hox 2002).

knowledge-intensive and endowed with a large potential of knowledge externalities and spillovers. The next graph, 2.1(e), with its criss-crossing, represents a complex interaction between economic performance and place. In some places there is support for the fostering effect of knowledge, while in others this is not the case. The final plot, 2.1(f), shows that small firms are similar in all regions, but especially the large firms vary from place to place. This is similar to 2.1(c), but this time this difference is achieved by some places having a high rate of high performing large firms.

Another way of portraying these varying relationships is to plot the between-place heterogeneity: the variation at level 2 (figure 2.2). In 2.2(a), all places have the same relationship, so there is no variation between places; in 2.2(b), there are differences between places, but they are unchanging with size. In 2.2(c), the differences between places increase rapidly with firm size, as they do in 2(f), while in 2(d) they decrease with size. The complexity of 2.3(e) is characterized by a between-place difference that is relatively large at all levels of size. The differing patterns of figures 2.1 and 2.2 are achieved by varying the slopes and intercepts of the lines. The slope measures the improvement of economic outcome associated with a unit increase in internal economies of scale input. The key feature of multilevel models is that they specify the potentially different intercepts and slopes for each place as coming from a distribution at a higher level.

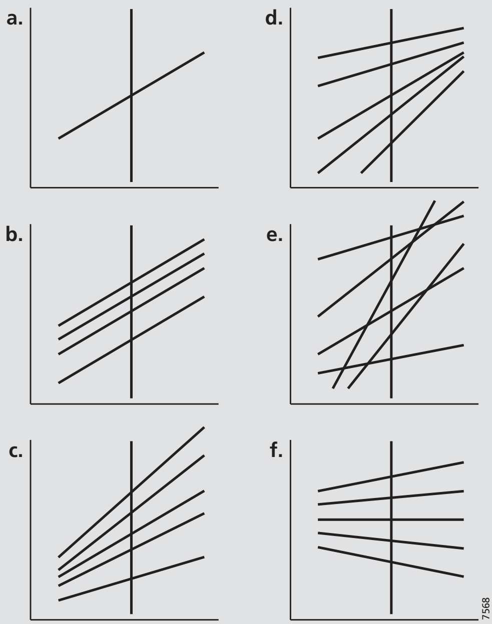

Figure 2.1 Varying relationships

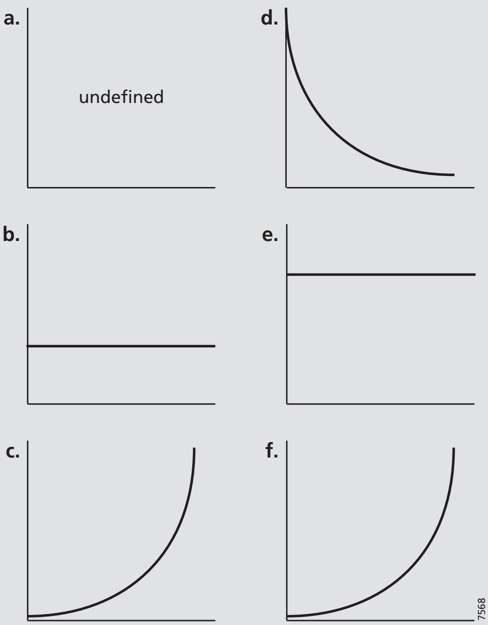

Figure 2.2 Between-place heterogeneity

2.3.4 Cross-level interactions[17]

One of the advantages of multilevel models is that additional predictors that refer not to individual characteristics, but to the nature of the places can be included in the model. Figure 2.3 depicts these relationships. Again, there is a two-level model (firms in places) with the response being firm performance, and the place-level predictor is the ecological variable, in our case external knowledge sources. Analogical to Jones et al. (1998), a very wide range of differing results based on this model are possible, of which a selection are shown in figure 2.3. In this figure, the vertical axes represent the response and the horizontal axes the ecological variable, while the lines on the graphs represent different types of firms (the dotted lines and the solid lines represent low-performing and high-performing firms, respectively). Thus, figure 2.3(a) shows that there are marked differences between low- and high-performing firms, but with no ecological effect. Figure 2.3(b) represents the converse situation: little difference in firm performance, but a large ecological effect. The parallel lines of figures 2.3(c) and 2.3(d) represent the cases when both the firm and ecological effects are marked and the ecological effect is the same for both categories. Figure 2.3(e) represents the case where the

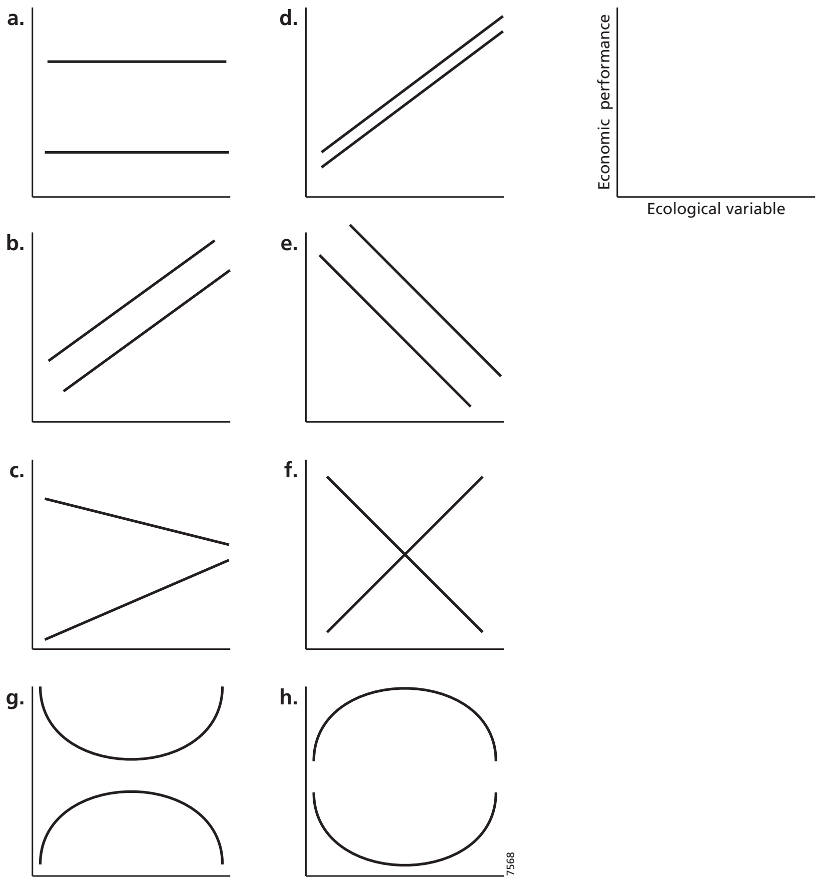

Figure 2.3 Cross-level interactions

17 Based on Duncan (1998)

ecological effect is negative for low-performing firms, but positive for high-performing firms so that in areas with large percentages of high-performing firms, the effects of externalities on low- and high-performing firms converge. Figure 2.3(f) represents the case where the ecological effects are so marked that the firm effects are actually reversed. Figures 2.3(g) and 2.3(h) show models in which non-linear interaction terms are of importance so that either the smallest or largest ecological effects are found at 'middling' levels of the contextual variable.

Once firm performance differs according to context, one of the most interesting topics is whether this is related to firm-specific characteristics. Investigating this requires analyzing interactions between variables on different levels of hierarchically structured data sets (see Kreft and De Leeuw 2004 and Hox 2002). We expect that certain firm-specific characteristics cause firms to be differentially influenced by certain aspects of their context and precondition them to profit from it. Firm internal competences can be considered a prerequisite for successful external learning. In line with Duncan et al. (1998), one can say that the concept of contextual influences on firm performance has long been a concern of spatial economic researchers and is the subject of considerable conceptual interest, and it is only with the development of the multilevel model that the full complexities of such relationships can be effectively analyzed. We must, therefore, anticipate heterogeneity, both between individuals and between contexts[18].

2.3.5 Formal notation

To recapitulate, in the preceding sections, we saw that 'contextual' effects are conceptualized as some places having uniformly higher rates of firm performance than others (in technical terms: having random intercepts). On the other hand, we saw that place can make a difference in the way that certain types of firms profit, but not all firms (in technical terms: having random slopes, inclusive of cross-level interactions). Multilevel analysis allows for both 'contextual' effects. The main advantage of both effects is that they can be used to assess the influence of cluster-level explanatory variables whilst controlling for differences in lower level explanatory variables (controlling for the compositional effects).

These kind of multilevel propositions can be expressed in formulas. It is assumed that we have data from J regions, with a different number of respondents (firms) n_j in each region. On the firm level, we have the firm performance outcome of respondent i in group j, Y_{ij}. There is an explanatory variable X_{ij} at the firm level and an explanatory variable at the regional level, Z_j. To model these data, a separate regression model is formulated in each group:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij} \quad (2.1)$$

The variation of the regression coefficients is modeled by a regional-level regression model:

18 In our empirical testing in the subsequent chapters, we therefore specify variables at both the micro and macro levels from which direct effects and cross-level interaction effects can be expected. We consider these cross-level interaction effects between the individual and the context as highly important for our research question. This requires the specification of processes within firms that cause those firms to be differentially influenced by certain aspects of the context. Our research therefore takes an eclectic approach, deriving some of our propositions from the management science and industrial organization literature and also drawing from economic geography and regional science and agglomeration studies.

$$\beta_{ij} = \gamma_{00} + \gamma_{01} Z_j + \mu_{0j} \qquad (2.2)$$

and

$$\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + \mu_{1j} \qquad (2.3)$$

The firm-level residuals e_{ij} are assumed to have a normal distribution with mean zero and variance σ^2_e. The regional-level residuals $\mu_{0j} + \mu_{1j}$ are assumed to have a multivariate normal distribution with an expected value of zero and to be independent from the residual errors e_{ij}. The variance of the residual errors μ_{0j} is specified as σ^2_e, and the variance of the residual errors μ_{0j} and μ_{1j} is specified as $\sigma^2_{\mu 0}$ and $\sigma^2_{\mu 1}$. This model can be written as a single regression model by substituting Equations (2.2) and (2.3) into Equation (2.1). Substitution and rearranging terms gives:

$$Y_{ij} = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j + \mu_{0j} + \mu_{1j} X_{ij} + e_{ij} \qquad (2.4)$$

The segment $\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j$ in Equation (2.4) contains all of the fixed coefficients; it is the fixed (or deterministic) part of the model. The segment $\mu_{0j} + \mu_{1j} X_{ij} + e_{ij}$ in Equation (2.4) contains all of the random error terms; it is the random (or stochastic) part of the model. The term $X_{ij} Z_j$ is an interaction term that appears in the model because of modeling the varying regression slope β_{1j} of the respondent-level variable X_{ij} with the group level variable Z_j.

Even if the analysis includes only variables at the lowest (individual) level, standard multivariate models are not appropriate. Multilevel models are needed because grouped data violate the assumption of independence of all observations. The amount of dependence can be expressed as the intraclass correlation (ICC), ρ. In the multilevel model, the ICC is estimated by specifying an empty model, as follows:

$$Y_{ij} = \gamma_{00} + \mu_{0j} + e_{ij} \qquad (2.5)$$

This model does not explain any variance in Y. It only decomposes the variance of Y into two independent components: σ^2_e, which is the variance of the lowest-level errors e_{ij}, and $\sigma^2_{\mu 0}$, which is the variance of the highest-level errors μ_{0j}. Using this model, the (ICC) ρ is given by the equation:

$$\rho = \sigma^2_{\mu 0} / (\sigma^2_{\mu 0} + \sigma^2_e) \qquad (2.6)$$

The intra-class correlation based on the null model can be reduced by including level 1 predictors if they vary systematically by region (the compositional effect) and by including specific level 2 predictors. The level 1 proportion can only be reduced by the inclusion of relevant level 1 predictors because the level 2 variables are constant at this level (Jones 1991).

Our outcome variable Y_{ij} is firm performance. In the regression line (2.1), β_{0j} is the usual intercept, β_{1j} is the usual regression coefficient (slope) for the explanatory variable, and e_{ij} is the usual residual error term. The subscript j denotes the region and the subscript i denotes individual firms. The difference from a typical regression model is that we assume that each region j has a different intercept coefficient β_{0j} and a different slope coefficient β_{1j} (since the intercept and slope vary across the regions, they are often referred to as random coefficients; see box 2).

The formulas represent the fact that multilevel models (1) allow for the simultaneous examination of the effects of ecological level and firm-specific predictors whilst (2) the non-interdependence of observations within regions is accounted for and (3) both inter-individual and inter-group variation can be examined (as well as the contributions of firm- and ecological-level variables to these variations).

2.4 To summarize

In the previous chapter we recognized that our research problem concerns relationships between variables that are measured at a number of (at least two) different hierarchical levels: 'the firm' (micro) and 'the region' (macro). Between these levels there exist multiple macro-micro and micro-macro relationships. In this chapter, we argued that analyzing these types of relationships requires a multilevel research framework. Multilevel analysis (1) offers the opportunities to determine whether 'the region matters' (being located in a region rich in knowledge resources is more conducive to firm performance than being located in a region that is less endowed with knowledge resources), once the unequal distribution of relevant firm-specific characteristics controlled for; (2) allows for the effect that, all else being equal, firm performance tends to vary with the average achievement in the region (this is what has been called random intercepts); and (3) incorporates the fact that firm performance tends to vary with certain firm-specific characteristics and possible cross-level interactions. In relation to the knowledge-based view of the firm as discussed in chapter 1, it can for instance be hypothesized that especially small or young firms profit from externalities because they have less ability to invest in knowledge themselves or because a certain absorptive capacity is required to profit from externalities.

3 The knowledge economy and urban economic growth[19]

Abstract

In this paper we contribute to the longstanding discussion on the role of knowledge to economic growth in a spatial context. We observe that in adopting the European policy strategy towards a competitive knowledge economy, The Netherlands is – as most European countries - mainly oriented towards industrial, technological factors. The policy focus is on R&D specialized regions in their spatial economic strategies. We place the knowledge economy in a broader perspective. Based on the knowledge economy literature, we value complementary indicators: the successful introduction of new products and services to the market ('innovation') and indicators of skills of employees ('knowledge workers'). Using econometric analysis, we relate the three factors 'R&D', 'innovation' and 'knowledge workers' to regional economic growth. We conclude that the factors 'innovation' and 'knowledge workers' are more profoundly related to urban employment and productivity growth than the R&D-factor. Preferably, urban research and policymakers should therefore take all three knowledge factors into account when determining economic potentials of cities.

3.1 Introduction

The concept of the knowledge economy is the central focus point of the European Union's socio-economic agenda. Five years ago the European Union launched an ambitious agenda for reform to set itself a new strategic goal for the next decade: to become the most competitive and dynamic knowledge-based economy in the world - capable of sustainable economic growth with more and better jobs and more social cohesion (EU 2000). But since, productivity has grown faster outside Europe and investments in research and development have not caught up with Asian and American levels. A recent report form the High Level Group in November 2004 advises that Europe needs to improve its productivity and employ more people by streamlining the Lisbon strategy even more to the direction of increasing and improving investment in Research and Development (R&D), the uptaking of ICT and contributing to a strong industrial base (EU 2005).

Also in the (economic) literature of the recent years the 'knowledge economy' has a great deal of attention: 'knowledge' is considered to play a crucial role as a powerful engine for growth. Despite this attention in policy documents and the literature it is not unambiguously clear what is meant by the 'knowledge economy'. Europe's strong focus on technological development and R&D is remarkable, but for good reason. R&D and high-tech economic activities have an overwhelmingly dominant share in the common statistics and indicators used. These data mostly stem from the OECD - an important promoter of the 'knowledge economy' -, which collects nearly sixty indicators aiming at measuring the knowledge-based economy (Godin 2004).

19 Raspe, O. and F.G. van Oort (2006) The knowledge economy and urban economic growth, European Planning Studies, 14(9): 1209-1234, Copyright © Routledge Taylor & Francis Group.

In this paper we wonder whether 'R&D' statistics as central indicators of the knowledge economy give sufficient insight in how the knowledge economy functions. This is especially important in relation to the economic growth potential of the knowledge economy. Besides a clear definition of knowledge economy, the spatial consequences of a knowledge economy are not unambiguously clear either. In this paper we therefore also focus on spatial patterns and differences in the knowledge economy in the Netherlands as a European example. Like most West-European national governments, the Dutch government has recently formulated a spatial vision on triggering the knowledge economy:

> 'The Dutch government aims to invest in the urban economy and work on building strong innovative regions. Fundamental knowledge development should aim at an applicable and competitive knowledge economy, in which research and development (R&D) investments are central. The Eindhoven region (South-East Brabant), because of its leading international position in R&D-investments, is therefore appointed as 'brainport' – and the region will be supported by spatial-economic and infrastructural policy initiatives by the Dutch government' (Nota Ruimte 2004, p.80).

This quotation from the most recent policy document on spatial planning in the Netherlands summarizes why we were motivated to apply a longstanding academic discussion on the role of knowledge to economic growth (Foray 2004, Acs et al. 2002) to the local and regional situation of the Netherlands. In this discussion, the role of innovation clusters and agglomeration economies is an important element (see Rosenthal and Strange (2006) for an overview). Starting in the early nineties of the last century, a vast quantity of empirical research has accumulated on the issue of agglomeration externalities. Models especially focus on the issue of isolating localized intra-industry (specialization) and inter-industry (variety) externalities contexts (Frenken et al. 2006). A problem in determining the exact nature and extent of local advantages of agglomeration is that they are context dependent on at least three dimensions: geographical, temporal, and sectoral. First, it is likely that local agglomeration externalities vary over countries, as factors affecting agglomeration forces, like labor mobility and spatial and economic policies, are different from one country to another. Second, it is plausible that the time frame matters. Agglomeration externalities will differ sharply between periods of economic growth and periods of decline. A third relevant aspect is the industrial context: firms in some industries benefit more from geographical concentration than their counterparts in other industries (Combes et al. 2004, Henderson 2003).

Relatively few empirical studies have satisfyingly focused on all three contexts simultaneously. Besides, a drawback of this literature is that it tests for the existence of statistically significant relations between indicators of agglomeration on the one hand, and industrial productivity and growth on the other. Whereas each of the different kinds of agglomeration benefits are embedded in mechanisms like spillovers and a range of cost savings due to concentration, none of these mechanisms is empirically modeled. This methodology, in fact, leaves the concept of agglomeration economies as a black box. This limits its usefulness for economic policy. This paper does not open the entire black box of agglomeration economies – but contributes to the discussion by determining different kinds of localized knowledge densities within economic growth clusters (each with distinctive causal relationships).

In this light, the choice of Eindhoven as central focal point for spatial-economic development in the Netherlands appears arbitrary. The central indicator being research and development investments, Eindhoven indeed ranks above all other Dutch municipalities because of the presence of many high-tech manufacturers (of which Philips is by far the largest) and a technical university. But do all agglomeration circumstances related to knowledge externalities fit best in the Eindhoven region? The Dutch economy consists mainly of service- and distribution based sectoral specializations, and hence a focus on technical innovation (measured by R&D) does not seem to encompass al opportunities in the Dutch knowledge economy. In this paper we agree that 'the knowledge economy' offers perspectives for economic growth, but that it is rather unclear what elements the knowledge economy actually consists of, how it can be fully measured in statistical indicators and in which regions and cities in the Netherlands the knowledge economy has its most significant imprints. One step further, the association of these imprints with employment and productivity growth on urban spatial scales is often difficult to measure because of data limitations (Drennan 2002). This paper focuses on these caveats in prior research. Indeed, many of the arguable 'stylized' conclusions on the spatial knowledge economy depend heavily on the definitions of such an economy, the research population and the spatial level of analysis. Because we are able to measure knowledge economy indicators at the municipal level in the Netherlands (n=469) our analyses are not subject to many of these restrictions. We use data for the period 1996-2003 for testing.

In short, we focus on three research questions. (1) Which causal aspects of the knowledge economy are discussed in the literature as important for urban-economic growth, and can all these be measured for the Dutch economy? (2) What spatial and sectoral overlap do these knowledge indicators have, and can they be reduced to uncorrelated 'pillars' (factors) of the knowledge economy? And (3) can a relationship between knowledge factors and economic growth on the urban cluster level be found for the Dutch case?

This paper is further organized as follows. The next section scans the literature for identifying knowledge economy indicators that are hypothesized to be related to economic growth. Eight indicators are distinguished and discussed on the municipal level. The third section uses factor analysis to synthesize the eight indicators into three distinctive factors. The fourth section presents the results of econometric models that link the three factors to employment and productivity growth on the cluster (urban) level in the Netherlands. The last section concludes and evaluates what insights are important for urban-economic policy.

3.2 Knowledge economy: definition and indicators

The recent attention paid to the knowledge economy is embedded in a longer tradition. During the 1960'ies the term 'knowledge economy' was introduced in publications of Machlup (1962) and Drucker (1959). In 1999, the concept was introduced in the dictionary for the first time, being 'an economy in which the production factors labor and capital are aimed on the development and application of new technologies'. This definition seems to fail on two aspects. Firstly, it does not define knowledge, while we have to know what knowledge is before applying it to an economy. Second, the ultimate goal of the knowledge economy appears to be the application of new technologies. This conceptualization is very much influenced by OECD-definitions (Godin 2004). As economists agree that the ultimate goal should be economic (employment and/or productivity) growth, there is debate on which knowledge-economic aspects best contribute to that. Because of this discussion, the theoretical and empirical literature has broadened the concept, from technological to also social and informational dimensions. We will discuss this literature shortly below, and distill (measurable) indicators from it. We start with the embedding of knowledge in organizations, filtering down into a definition of knowledge and knowledge economy, then followed by a discussion of the indicators that are related to urban-economic growth.

In analyzing the possible spatial effects of knowledge of economic growth, it is necessary to have a closer look at the role of knowledge and knowledge transmission in organizations. Because activities in organizations have to be integrated, co-ordination of these tasks and functions is at the heart of the organization's economic process. In general, co-ordination of tasks and functions induces costs. Knowledge about processes and products makes this co-ordination more efficient and less costly. The knowledge economy, especially the information density because of ICT's, can make time and physical distance less stringent constraints for economic functioning and production chains of organization potentially are reduced, either by internal vertical integration and/or external oriented vertical disintegration. The picture becomes more complex when the efficiency of tasks that depend on non-codified knowledge is related to the availability of knowledge. This is particularly valuable for the quality and innovation of production and where non-codified, tacit knowledge is important. It becomes necessary to look at the transformation of information into knowledge. This does not mean that codified information and cost-efficiency are not important, but that the balance of relevant aspects changes. More emphasis on knowledge networks coincides with a growing importance of knowledge attached to human capital and transactional relations within and between organizations. The knowledge-based organization differs substantially from the classical organization. Knowledge is at the core of the enterprise and labor changes from a cost into an essential investment. Production processes aim at the creation of immaterial knowledge-structures. Consumer and business relations become part of more personalized networks in which interaction and face-to-face contacts prevail. These immaterial assets determine increasingly, and complementary to material assets, the value of an organization.

In the above vision, knowledge transforms information and data into useful applications for businesses that lead to economic (productivity) growth. Most information that people come across is still unstructured and chaotic. Knowledge concerns the structuring and application of information. Only with knowledge, information becomes meaningful. Knowledge can be obtained and trained by experience, familiarity, science or learning. Often knowledge is taken together with innovation: the commercial exploitation of knowledge. To encompass al these elements of knowledge conceptualization, we propose a broad definition of knowledge economy. Knowledge then is the adding up of abilities (capabilities, creativity and persistency) to recognize and solve problems, by collecting, selecting and interpreting information. 'Change' is an essential element in this. The knowledge economy then is the use of knowledge in interactive relations between market actors and others, while producing and using goods and services, from the first idea to final products. This definition does not focus solely on technological renewal as goal of a knowledge economy, but on productivity and employment growth of firms.

Reading the (large) literature on this, we come across eight (measurable) indicators that connect knowledge economy and economic development. We will discuss them shortly. More information on the indicators and their respective theoretical background can be found in Raspe et al. (2004).

See also table 3.1 (and appendix 3.1) for the sources of the empirical indicators (translated from the literature) used. The first aspect that is central in many studies is the role of education and professional capabilities. Many studies focus on these forms of human capital as crucial conditions for a knowledge-based economy (Lucas 1988, Mathur 1999). A capable and highly educated workforce has more opportunities to absorb and use information. Firms with such a workforce are more competitive, since search costs are lower. In spatial- economic terms it is good to have a highly educated and capable workforce in the surrounding of firms – a labor market characteristic. This is often the case in larger urban agglomerations. Recently, Florida (2002) replaced human capital as source of entrepreneurship and economic growth by creative capital. The difference with human capital theory is that the creative class (as Florida labels knowledge workers and artists) not necessarily needs to have a high educational level in order to create more than average added value in and with their work. Besides direct productivity effects by hardworking knowledge workers, Florida distinguishes indirect, localized growth effects from consumptive power of the creative class, in amenity–rich urban environments in which they live. Because his research shows (although not unambiguously accepted) that creativity as motor for local economic potential can be considerable, we added the presence of creative industries (distinguished by the Florida-definition in Dutch labor force data) in our analysis as second knowledge economy indicator.

Both creative and human capital theories measure person bounded and more communicative aspects of knowledge, stored in employees and entrepreneurs. The literature distinguishes two more conceptualizations that focus at the communicative aspects of knowledge and knowledge transfer. A large literature focuses on the growth potentials of firms due to an increased accessibility of information through information- and communication technologies (ICT) in their entrepreneurial operations, especially in urban areas (Drennan 2002). In theory, ICT as a general-purpose technology can accelerate organizational processes in terms of productivity. Contrary to other communicative indicators, ICT functions as an optimal vehicle of knowledge transfer when information is codified. We take this aspect (measured by computer usage per employee per 5-digit industry, localized in municipalities) as third indicator in our research. Fourth, much social-economical research focuses on social, cultural and communicative capital as sources for productivity gains in economic sectors (Cooke and Morgan 1998). This conceptualization looks at trustworthy connections between economic actors as sources of social and economic networks. Especially communicative skills are required in that sense, and the ability to persuade and convince others. This not only requires capabilities of employees, but also from the quality of the (selection) environment in which they operate. An indicator based on communicative skills in network relations (first developed in McCloskey and Klamer 1995) is applied to the detailed municipal industry structure in the Netherlands, and functions as fourth indicator. We have to remark that, contrary to what the individual literatures try us to believe, theories on creative and human capital, communicative persuasiveness and ICT-sensitivity share a lot of common ground. We will come to this point later.

Our definition of the knowledge economy also addresses more technical and production oriented aspects of economic renewal that (endogenously) can lead to economic growth of firms. By tradition, the largest amount of literature focuses on these aspects (that are also central in the dictionary definition). The largest attention of governments and institutions is being paid to research and development (R&D) as sources of growth, because this input factor can be stimulated by subsidies (Acs 2002). Although not all R&D-activities lead automatically to innovative output and growth (Black 2004), we use the number of R&D employees in firms as fifth indicator in our analysis. A special, and according to many independent indicator of R&D-activity, occurs when R&D-intensive firms cooperate in international networks, and their export is also technology driven. In those cases the literature speaks of high- and medium tech economic activities, which overrepresentation functions as source for internalizing macro-economic growth Cortright and Mayer 2001). An indicator of relative overrepresentation of high- and medium tech industries is used as sixth indicator in our analyses. Innovation is generally regarded as the most import knowledge economic key source for economic growth. R&D is an input-indicator of innovation (intentions); it does not measure actual innovative output of firms.

Several sources for innovative output exist (Jaffe and Trajtenberg 2002): patens and patent citations, copyrights, new product announcements and questionnaires in which firms are in great detail asked about their innovative behavior (products and processes new for the market and new for the industry in which one operates).

In our paper we agree with Acs et al. (2002), who indicate that in order to understand the exact role that knowledge and, therefore, innovation plays in the economy, the measurement of knowledge inputs (as R&D expenditures), intermediate output (such as the number of inventions which have been patented) and knowledge outputs (such as new product sections) is critical. The valorization

Table 3.1 Descriptive statistics of eight indicators of the knowledge economy

	Mean	Standard Deviation	Minimum	Maximum
1. Education level[l0]	1.92	0.08	1.76	2.21
2. Creative economy[2]	2.03	1.58	0.26	20.84
3. ICT-sensitivity[1]	0.75	0.11	0.53	1.27
4. Communicative skills[3]	0.53	0.08	0.33	0.80
5. R&D[5]	2.81	1.09	1.00	5.00
6. High-tech & Medium-tech[4]	7.70	4.69	0.00	27.00
7. Tech. Innovation[6]	3.00	1.40	1.00	5.00
8. Non-tech. Innovation[6]	3.00	1.38	1.00	5.00

n= 496 (Dutch municipalities)

0 The education level is the weighted average (respectively with the weights: 1,2,3) of the educational levels: high (university – WO- and higher vocational education – HBO-), middle (intermediate vocational education – MBO-, higher general secondary education – HAVO- and pre-university education – VWO-) and low (lower general secondary education – MAVO- and lower vocational education – LBO-)

1 The number of computers and terminal per sector (National Statistics; Computerization survey) is linked to the population firm establishments of on the level of municipalities (LISA database): the indicator measures the number of computers and terminals per employee on the level of a municipal.

2 Based on Manshanden et al. (2004).

3 Based on classification by McCloskey and Klamer (1995).

4 High-tech and medium-tech firm are classified by their (detailed) SIC codes by their extend of research and export orientation, see OECD (2003).

5 The original indicator of R&D intensity per sector per Dutch province form the third Community Innovation Survey (CIS3, Statistics Netherlands) is redressed to municipalities (based on LISA database). See: De Bruijn (2004) In this paper we constructed an interval variable based on map 13 (p. 73) in Raspe et al. (2004)

6 Based on Raspe et al. (2004). The original indicator of the innovation intensity per sector per Dutch province form the third Community Innovation Survey (CIS3, Statistics Netherlands) is redressed to municipalities (based on LISA database). See: De Bruijn (2004). Innovation are registered as products and services, which are new in the market of sector. In this paper we constructed an interval variable based on map 14 (p. 75) and 15 (p. 77) in Raspe et al. (2004)

phase of innovation processes should be included in studying localized economic dynamics. In this valorization, it is important to distinguish between technological and non-technological innovations. Both aspects are introduced in our analyses, by focusing on successful innovations as reported in the third Community Innovation Survey (CIS3) of Statistics Netherlands and EUROSTAT. They are the seventh and eight' indicator in our analyses.

Most indicators measure the relative municipal employment specialization in the workplace of employees. We frequently use shift and share analysis to distribute regional data to the municipal level. Because of a large sectoral detail (we distinguish up to 728 industries) our indicators resemble actual municipal data to a large extent (Van Oort 2004). Table 3.1 gives descriptive statistics of the eight indicators used in our analysis. Individual maps of all indicators can be found in appendix 3.1.

3.3 A synthesis of spatial knowledge indicators

In the previous section different aspects of the knowledge economy were introduced: the level of education of the working population, ICT-related employment, innovation (output), research and development (innovation input), the representation of high-technology sectors, and skills related to handling information and creativity. The spatial repercussion of this complex of indicators differs a lot. But a lot of indicators also showed spatial association. In this chapter we will distillate and describe independent dimensions (factors) that form the underlying level of the eight indicators and that can be seen as independent pillars in the urban knowledge economy. All eight indicators were standardized. We first carried out a factor analysis with VARIMAX-rotation[20] to group the municipal scores of the eight indicators of the local knowledge economy into spatially independent underlying factors. Often, this also means sectoral (in)dependence. For example the spatial correlation between the level of education and the use of ICT seems obvious: highly

Table 3.2 Factor scores in the knowledge economy

Indicators:		**Factors:**	
	Factor 1 'Knowledge workers'	Factor 2 'Innovation'	Factor 3 'R&D'
ICT-sensitivity	**0.753**	0.365	0.268
Education level	**0.949**	0.164	0.044
Creative economy	**0.516**	0.024	-0.198
Communicative skills	**0.927**	0.040	-0.069
High-tech and medium-tech	-0.175	0.146	**0.840**
Research and Development	0.080	0.129	**0.836**
Innovation (technological)	0.130	**0.878**	0.246
Innovation (non-technological)	0.147	**0.914**	0.054

20 Factor analysis is a statistical technique to identify the underlying variables (named factors) in a dataset in which multiple characteristics are included, that simultaneously show mutual correlation. This technique is often used to remove the overlap between the different indicators and reduce the characteristics to independent factors: the similarity within a factor is high while low between the factors.

educated employees more often use computers in their business processes - on the sectoral level the correlation is 0.36 (the spatial patterns show an even stronger correlation: 0.58). Of course, section 3.2 made clear there are also theoretical motives that clarify why the eight indicators are different.

The result of the factor analysis is a three-factor structure. Table 3.2 shows the factor scores: the correlation between the eight individual indicators and the three remaining factors. The three factors can relatively unambiguously be interpreted. The third factor, labeled 'R&D', is usually most identified with the knowledge economy. The factor is closely related to the indicators research and development and the relative presence of high-tech and medium-tech enterprises. Concerning their content, there is a large overlap between these two indicators. R&D is an input factor in knowledge processes. The factor labeled 'innovation' is build up by the indicators of innovation output, both technological and non-technological in character. Locations that have high scores on this factor contain relatively many enterprises that introduced new products or services to the market or carried out new business processes in the recent years. Remarkable is that the non-technological innovators are smaller in number of employees, but are spatially concentrated in the same regions as the technologically oriented innovators. The factor 'innovation' combines both types. Remarkably, the number of employees that carry out research and development is sectorally and spatially clearly a different indicator than the outcome of research, innovation. After all, not every research leads to new products or services. The factor 'knowledge workers' finally, shows high scores on ICT-sensitivity, education level, employment specialized in communicative skills and the amount of creative economic sectors. As mentioned in section 3.2, this common conceptual ground did not come as a big surprise. Generally, this factor is characterized by employment specializations with a high degree of human capital. Locations with high factor-scores are in the frontline of the ICT and information economy. These knowledge workers are important in the diffusion process of knowledge, not only codified knowledge but also the more difficult transferable tacit knowledge (Van Oort et al. 2003). Due to their skills, creativity and modern ICT-applications, knowledge workers guide in economic renewal and diffusion processes especially in relation to business services. It is important to consider this (less 'hard' and therefore often neglected) dimension simultaneously with the (technical) industrial factors -R&D and technological innovation. After all might equally qualify as conditions or sources for economic renewal.

The spatial patterns of the factor scores are presented in figures 3.1, 3.2 and 3.3. Figure 3.1 shows the spatial pattern of the factor 'knowledge workers'. In this pattern we see a hierarchical structure on levels of urbanity: the highest average factor scores are in cities and in the Randstad region. Large cities like Amsterdam and Utrecht as well as their suburban surroundings have relatively high scores on this factor. Hilversum with the specialization on media activities has a top position. But also The Hague, Delft and Leiden have economies highly driven by knowledge workers oriented firms. The logistic region Rotterdam has a position in the highest interval, but is lacking behind when compared to Amsterdam, The Hague and Utrecht. Also a number of medium-sized cities in the intermediate zone of the Netherlands (the region adjacent the Randstad region) specialize in economies that are characterized by knowledge workers. The rural regions and the regions in the national periphery of the Netherlands are lagging behind in intensity of this employment.

The map of the second factor, 'innovation' (figure 3.2), shows a different spatial pattern than that of the knowledge workers specialization. Especially regions in the western part (the Randstad), and the eastern part of the Netherlands show a higher degree of innovative businesses. The region

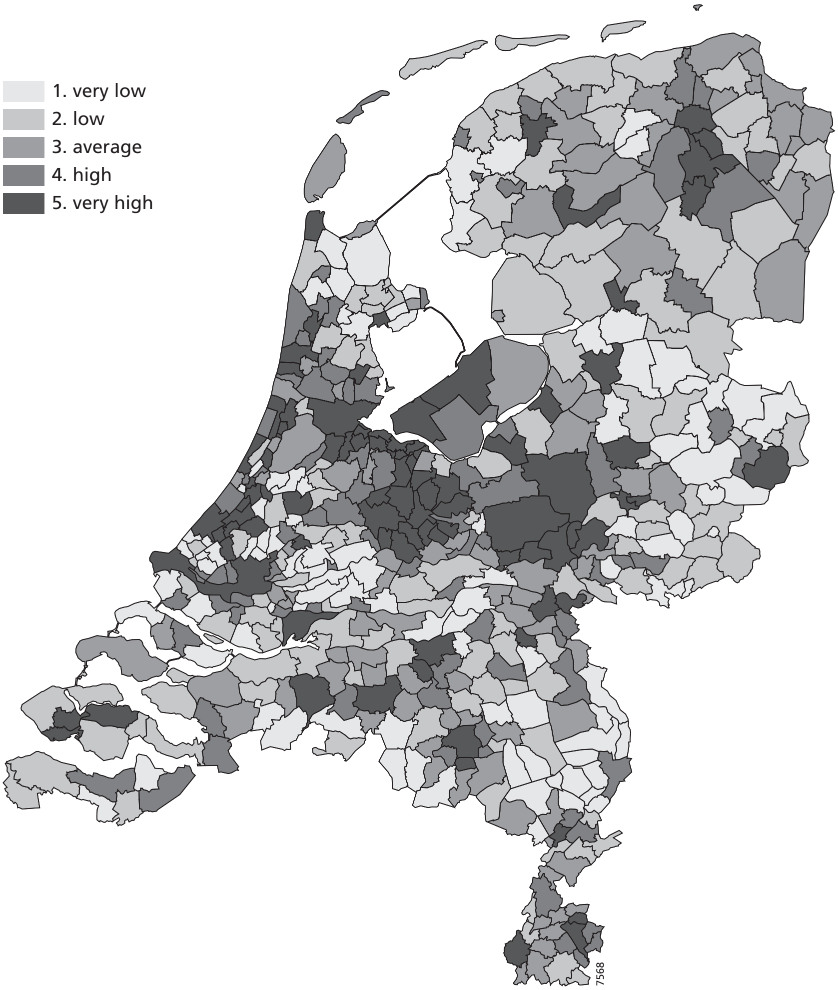

Figure 3.1 The 'Knowledge workers' dimension (factor 1)

Amsterdam, and the areas nearby this city are relatively innovative in character. Also Rotterdam forms the center of an innovative region. Some clearcut chemical industrial clusters like Sittard-Geleen (DSM) and Terneuzen (DOW Chemicals) form innovative hotspots. Remarkable is that the centrally located Utrecht region relatively lacks behind in the representation of innovative businesses. Although the actual distribution over municipalities differs considerably from that of the factor knowledge workers, on average there still exists a hierarchy over urban levels: cities and urban parts of the Netherlands have on average high scores. Municipalities in the Randstad region, larger cities and central areas of urban agglomerations still come to the fore as the foci of innovative activities. The hierarchy is less distinctive as in the knowledge workers variable.

The spatial pattern of the third 'R&D' factor (figure 3.3) again differs form the knowledge workers and innovating regional patterns. The regions in the western part of the Netherlands, which showed strong orientations to the knowledge workers and innovators dimensions, are characterized by

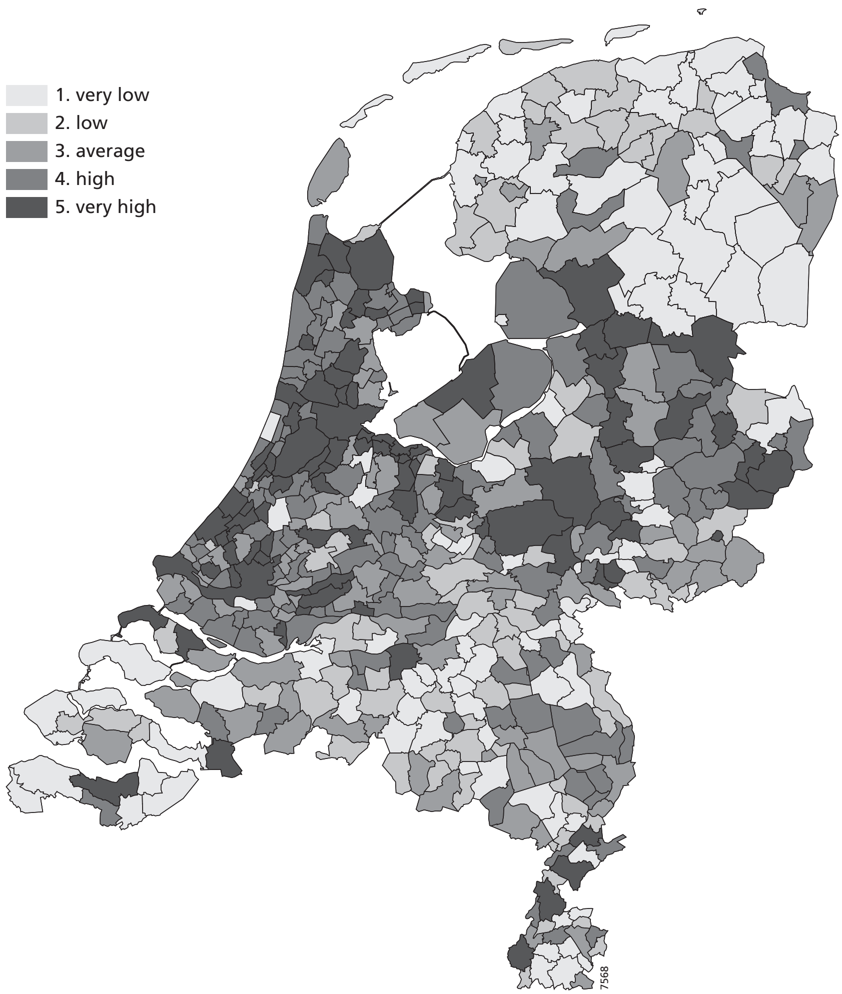

Figure 3.2 The 'Innovation' dimension (factor 2)

relatively low degrees of R&D activities. Not the (largest) cities and the most dense economic parts of the Netherlands, but the regions in the southern and eastern part of the country are in front of (relative) R&D-employment specialization. These are the regions that have a stronger industrial orientation, the regions that functioned as an overflow area for the industrial activities that left the Randstad and other dense parts (Van Oort 2004). The Eindhoven region (with Philips and ASML) and several other cities containing technologically oriented multinational firms and technical universities (like Tilburg, Wageningen, Delft and Terneuzen) are R&D hotspots in the Netherlands. On average an urban hierarchy does not apply to the R&D-factor. Municipalities in the Randstad region, in the largest cities and in central areas of cities have the lowest average scores on the R&D-factor. Instead, the municipalities in the intermediate zone of the country, medium-sized cities and the non-urban areas in terms of labor market connectedness have economic structures that best link to the R&D-factor.

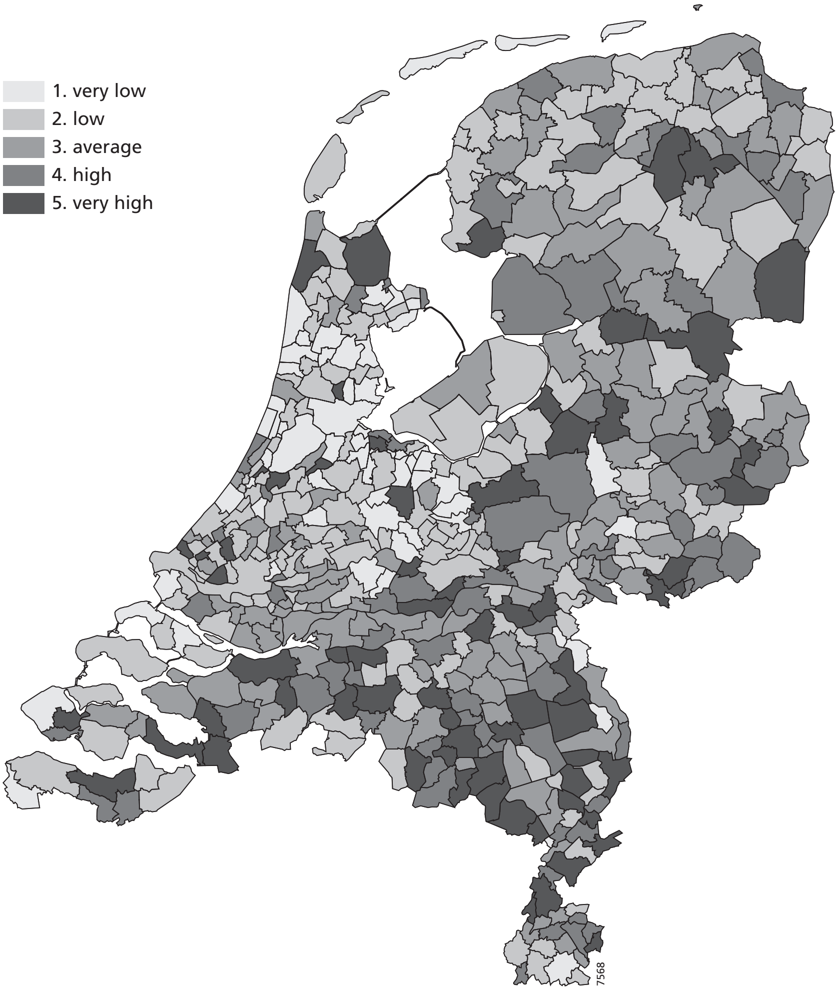

Figure 3.3 The 'R&D' dimension (factor 3)

To summarize - we distinguished 8 indicators of the knowledge economy that can be reduced to three independent pillars of sectoral typologies of firms with different spatial imprints: 'knowledge workers', 'innovation' and 'research & development'. In the next paragraph we now turn to the relation between these three knowledge factors and economic growth.

3.4 Econometric analyses on employment and productivity growth

To test the relation between the knowledge intensity of businesses and their economic performance we link the knowledge factors to two dynamic economic performance indicators in an OLS-framework of analyses, controlling for other agglomeration variables: employment growth and productivity growth. Both growth indicators refer to municipal data (n=496) for the period 1996-2003. Productivity is measured as labor productivity: the gross added value per employee (in full

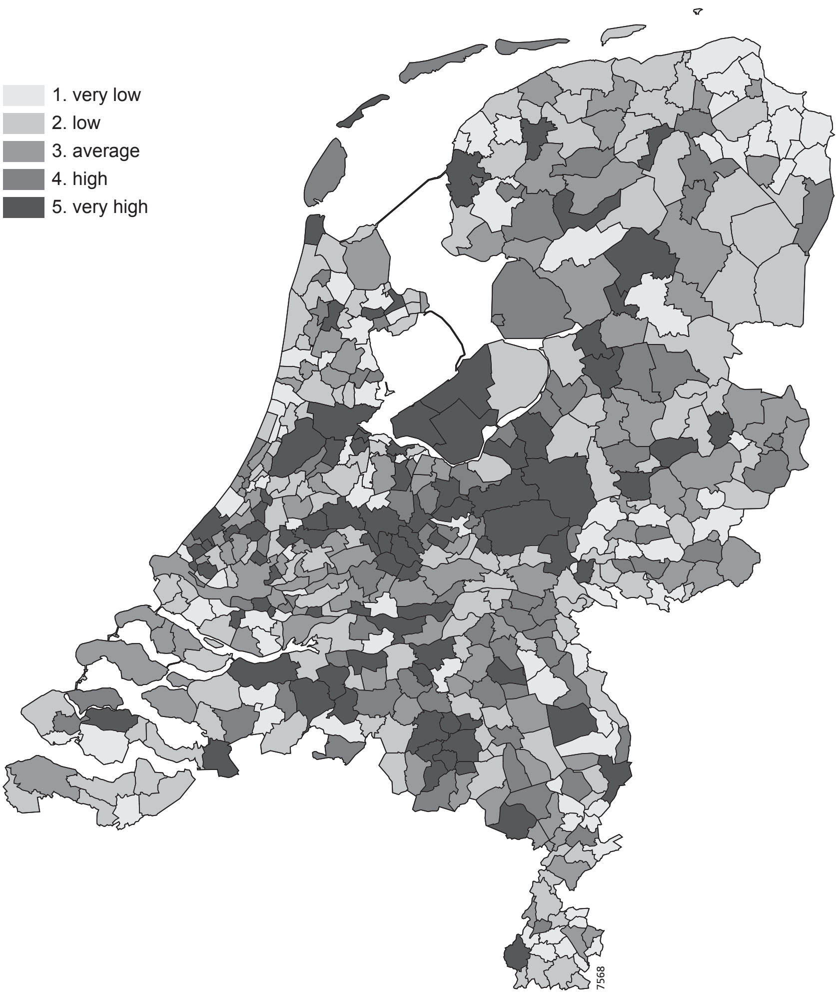

Figure 3.4 Employment growth 1996-2003 (log)

time equivalents). Both employment and productivity growth are defined as the log (level 2003 / level 1996). Figures 3.4 and 3.5 show the spatial patterns of both dynamic performance indicators. In general, large and medium sized cities have a higher gross added value, but also show higher productivity levels. Labor productivity is highest in the western part of the Netherlands (the Randstad region) in which the four big cities Amsterdam, Rotterdam, The Hague and Utrecht are located. Employment growth in 1996-2003 was the highest in this Randstad region and in medium-sized cities outside this region. Suburban regions show high growth figures as well. For productivity growth the catching-up effect of rural and regions in the national periphery appears substantial (in the most productive regions it is more difficult to grow the same rate as regions that grow from a relative small base).

Table 3.3 shows the descriptive statistics of all variables used in the analyses in this section. In testing the relationship between knowledge intensities and economic performance we introduce

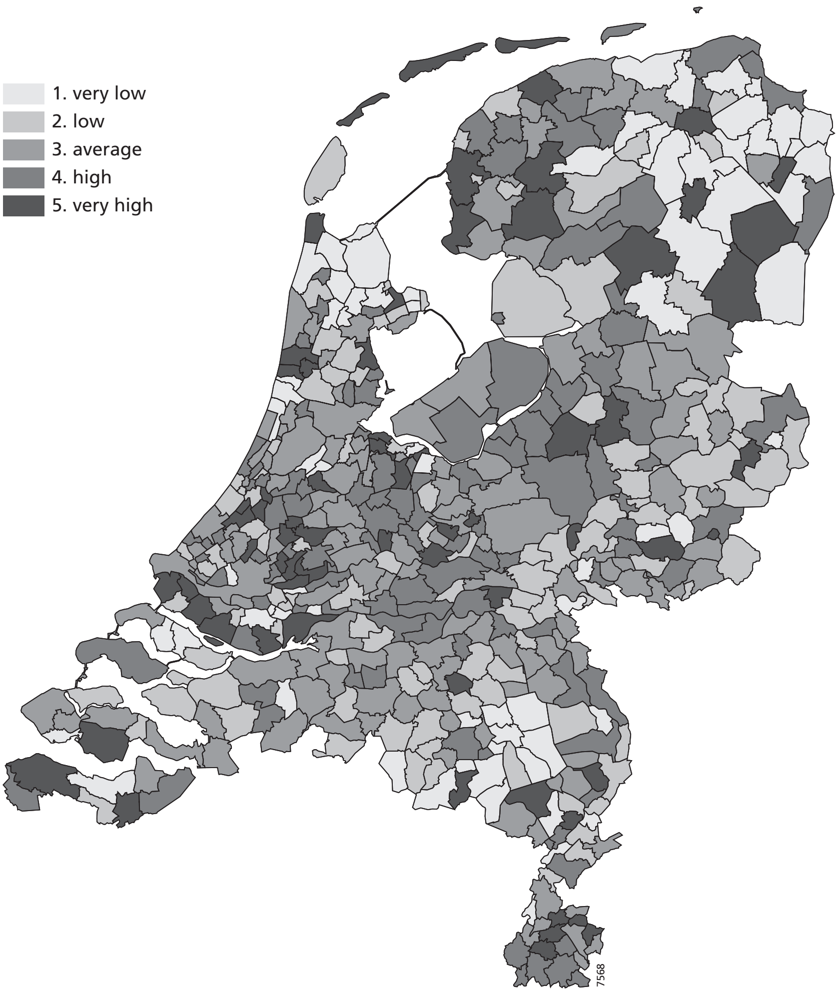

Figure 3.5 Productivity growth 1996-2003 (log)

relevant control variables for agglomeration attributes other than the localized knowledge indicators (Van Oort 2004). A Dutch municipal data set on sectoral employment structures is used to construct control variables of various types of agglomeration economies - as hypothesized in the second section. Those indicators are as reminiscent as possible to those used in prior studies (Henderson 2003). Economic growth is determined by both local and national circumstances. The Netherlands is relatively urbanized with a population density of over 450 inhabitants per km^2 - this is of interest because it is small enough to offer a natural control for location-specific cultural attributes. Within the country, cultural and economic differences between locations are simply less important and more easily controlled than they would be between the major U.S. cities considered in previous studies. Still, the local or regional determinants influencing the productivity of firms embody external and agglomeration factors (localization and urbanization economies). We want to test whether initial spatial circumstances are connected to subsequent agglomeration processes (a 'sources of growth' analysis). Therefore, explanatory variables are constructed using data from the

Table 3.3 Descriptive statistics of performance and control variables

	Minimum	Maximum	Mean	Stand.dev
Employment growth (1996-2003)	-2.62	5.84	0.06	1.12
Productivity growth 1996-2003 [log]	-0.09	0.36	0.08	0.04
'Knowledge workers' [factor 1]	-2.23	3.89	0.00	1.00
'Innovation' [factor 2]	-2.11	2.14	0.00	1.00
'Research & Development' [factor 3]	-1.91	3.95	0.00	1.00
Specialization industrial activities [log]	-1.56	0.58	-0.04	0.32
Specialization distribution activities [log]	-0.57	0.42	0.04	0.17
Spec. producer services [log]	-0.72	0.43	-0.16	0.19
Variety 1996 (HHI, n=49) [log]	-2.98	-0.86	-2.41	0.29
Population density [log]	1.42	3.81	2.63	0.45
Investment level [log]	3.96	4.45	4.11	0.06
Wage level [log]	4.19	4.65	4.39	0.07
Supply business areas growth [log]	-0.48	0.82	0.09	0.16
Employment level 1996 [log]	-2.75	3.84	0.03	1.04
Productivity level 1996 [log]	4.48	5.02	4.70	0.06

n= 496 (Dutch municipalities)

Sources: see table 3.1, Frenken et al. (2006), Raspe et al. (2004) and Van Oort (2004).

base year (1996) to reduce problems of simultaneity as much as possible[21]. Theories on clustering and intrasectoral knowledge spillovers contend that knowledge is predominantly sector-specific and hence that regional specialization will foster growth. *CONCENTRATION (LQ)* is defined as a location quotient showing the percentage of employment accounted for by an industry in a municipality relative to that percentage nationally. It is calculated for three broad basic sectors: for industrial, distribution and business service activities. This indicator in particular comprises (intra-industry) localization or specialization economies. Alternatively, an opposing body of literature contends that regional diversity in economic activity will result in higher growth rates as many ideas developed by one sector can also be fruitfully applied in other sectors. In accordance to the literature, economic diversity is introduced by means of a Hirschman-Herfindahl-index of employment distributions over 49 sectors in all 469 municipalities – actually measuring the lack of diversity. We further introduce initial conditions of indicators that account for local-economic particularities present in certain spatial units that work out (positively or negatively) for all firms in different industries in the same manner. *EMPLOYMENT LEVEL* and *PRODUCTIVITY LEVEL* measure absolute employment and productivity values per municipality, and control for localized start-of-period development bases. Industry differences in wages are controlled using *WAGELEVEL*, measuring the industry wage rate in 1996 at the regional level. The initial wage level

21 The 'Innovation' and 'R&D' indicators are measured in 2002, but reflect the CIS questionnaire in which is asked about the renewal in products, services and process over the previous two years. Data on R&D and innovation before 2002 are incomparable for analysis. Compared to the other variables used in the models, this implies a time lag in the variables of innovation and R&D, what might induce endogeneity Jaffe (1989) shows in a knowledge production function setting in the US that spatial patterns of innovation indicators are to a large degree stable over time.

and the initial employment level[22] and productivity level are hypothesized to have a negative relation with growth performances. Population density is used as a proximate indicator of urbanization externalities stemming from a large concentration of economic activity per se, irrespective of its composition.

The main component of urbanization economies is the benefits from market size. *INVESTMENT LEVEL* concerns investments in immobile capital goods, excluding houses. The indicator is computed per fte, and data are taken from Statistics Netherlands (CBS). Newly built business premises attract economic activity that previously was not present in that location. To control for these potential causes for extreme high differential employment growth we included the growth in business sites in hectares (average 1996-2002) from the IBIS-database (see Van Oort 2004). Because border regions may have different economic growth figures due to (unmeasured) foreign economic concentrations (like the Ruhr-region in Germany of the Antwerp region in Belgium), a dummy variable was constructer for border municipalities.

Table 3.4 shows the results of the econometric models on the municipal level (n=496) of employment and productivity growth. For multicollinearity reasons we do no include highly correlated variables (see correlation table in appendix 3.2). The three knowledge-economy factors by definition (because of the *VARIMAX*-rotation in the factor analysis) are statistically independent. Regarding endogeneity, an unobserved characteristic of a municipality may affect patterns of economic location, which feeds back through establishment behavior to affect the level of agglomeration. This problem is especially troublesome when measuring employment growth. One option is to instrument for the agglomeration variables – but because it is unclear how these instruments are appropriately constructed we took another (and simpler) approach. So as to minimize the importance of location-specific factors, it is tested whether dummy variables (fixed effects or random effects) should be included in the employment growth models for each of the 40 NUT3-regions represented in the data (as in Henderson 2003). The NUTS-3 regional level is of key important for investment-, export-, wage- and labor market characteristics (Frenken et al. 2006). The first (LSDV) model, introducing only the three knowledge economy factors, proved to be better specified when introducing fixed effects (using a Hausman test on random versus fixed effects). Test statistics of spatial (municipality) dependence reveal that no spurious spatial autocorrelation is present when using fixed effects estimation. The second (OLS) model introduces all control variables as well. From the Hausman test it becomes clear that fixed effects estimation is not superior to random effects estimation. Subsequently, from the LM(BP) test it turns out that region-specific random effects are not superior to OLS-estimation, because of a lack of a form of heteroskedasticity. We therefore used OLS-estimation. In this case, spatial autocorrelation remains an issue in the estimation. Therefore, the third model estimates a spatial error model. The spatial coefficient turns out to be significantly positive. In the productivity growth models, NUTS-3 regional random effects are introduced (after performing a Hausman test on random versus fixed

22 Combes (2000) shows that including the level of the local sectoral employment in the analysis strongly changes the interpretation of the specialisation variable and leads to an overestimation of the localisation economies. Actually, the impact of the share of the sectoral employment in total employment, holding the level of the sectoral employment constant, is simply the inverse of the effect of the total employment . Thus, it cannot be interpreted as intrasectoral local externalities. The correct interpretation is obtained if the level of the sectoral employment is replaced by the level of the total employment in control variables – what is done in our analysis.

Table 3.4 OLS models on employment and productivity growth in municipalities in the Netherlands (n=496, t-values in parentheses)

	Employment growth 1996-2003 (log)						**Productivity growth 1996-2003 (log)**			
	LSDV		OLS		Spatial error		FGLS		FGLS	
Constant	-0.714	(-1.01)	0.164	(0.926)	0.052	(0.23)	-0.001	(-.01)	0.018	(0.39)
Fac1 'Knowledge workers'	0.427	(7.88)**	0.218	(2.48)**	0.277	(2.99)**	0.056	(1.19)	0.315	(4.08)**
Fac2 'Innovation'	0.258	(4.33)**	0.099	(1.87)*	0.162	(2.89)**	0.056	(1.17)	0.109	(2.29)**
Fac3 'R&D'	-0.002	(-0.04)	0.059	(1.10)	0.051	(0.91)	-0.139	(-2.99)**	-0.130	(-2.54)**
LQ industrial activities (log)	-		0.077	(1.01)	0.053	(0.69)	-		0.168	(2.34)**
LQ distribution (log)	-		0.175	(2.95)**	0.196	(3.23)**	-		0.115	(2.10)**
LQ producer services (log)	-		0.093	(1.56)*	0.093	(1.56)*	-		-0.069	(-1.23)
Herfendahl index (log)	-		0.250	(4.15)**	0.276	(4.52)**	-		0.148	(2.65)**
Population density (log)	-		-0.112	(-1.71)*	-0.129	(-1.89)*	-		-0.043	(-0.74)
Investment level (log)	-		0.098	(2.08)**	0.117	(2.49)**	-		0.009	(0.25)
Wage level (log)	-		-0.106	(-2.19)**	-0.089	(-1.75)*	-		-0.008	(-0.18)
Supply business areas (log)	-		0.014	(0.31)	0.021	(0.460)	-		0.048	(1.16)
Dummy border regions	-		-0.229	(-1.75)*	-0.229	(-1.57)*	-		0.094	(0.79)
Employment level (log)	-		0.414	(5.95)**	0.376	(5.26)**	-		-	
Productivity level (log)	-		-		-		-		-0.307	(-6.35)**
Lambda (spatial coefficient)	-		-		0.799	(5.98)**	-		-	
Regional fixed effects	Yes		No		No		No		No	
Regional random effects	No		No		No		Yes		Yes	
R2	0.276		0.246		-		0.031		0.135	
LIK	-681.75		-699.03		-690.12		-		-	
Hausman	15.97	(0.001)	9.40	(0.742)	-		0.62	(0.892)	16.31	(0.233)
LM (BP)	-		3.75	(0.053)	-		13.06	(0.000)	30.90	(0.000)
LM (ρ, w_1)	0.818	(0.366)	2.826	(0.092)	-		2.309	(0.128)	0.349	(0.554)
LM (λ, w_1)	2.077	(0.149)	10.890	(0.000)	-		2.490	(0.114)	0.573	(0.449)
LR (λ)	-		-		7.822	(0.005)	-		-	
LM ρ (λ)	-		-		0.042	(0.837)	-		-	

** significant at 0.05, * significant at 0.10. OLS-models with fixed effects are usually referred to as Least Squares Dummy Variables (LSDV) Models (Greene 2000, p.560). FGLS (Feasible Generalized Least Squares) reports for regional random-effects models. Hausman reports on the Hausman tests of random versus fixed effects (p-value). LM (BP) reports on the Breusch-Pagan Lagrange Multiplier test of significance of random regional effects (p-value). LM (r) and LM (l) are statistics for the presence of a spatial lag in the dependent variable and in the residual respectively, following Anselin et al. (1996), (p-values). LR(l) tests for the significance of the spatial dependence coefficient (p-values). The spatial weight matrix used is that of the (row-standardized) inverse distance weights w_1 (row standardized). Additional tests have been performed with inverse distance squared (w_2) and tripled (w_3) weight matrices. LQ stands for location quotient, LIK for log likelihood.

effects) in the fourth model in table 3.4 with only the knowledge indicators as explanatory variables. The explanatory power of this FGLS-model is extremely low. The fifth model introduces the control variables. Again, FGLS-estimation appears optimal. In both models 4 and 5, no signs of spatial autocorrelation are found.

From table 3.4 it becomes clear that there is a significant (positive) spatial relation between the 'knowledge workers' factor and the 'innovation' factor and localized employment growth. R&D intensities are not significantly related to employment growth on the municipal level. This robust outcome holds also after controlling for all other variables, fixed-effects and spatial autocorrelation. Most controlling variables perform as expected: local specializations in distribution and producer service activities are positively related to employment growth; as are the investment and employment levels in the base year. Negatively related to localized employment growth are the initial wage level and sectoral variety (and to a lesser extent population density). In the productivity growth models, coefficients of the 'knowledge workers' dimension, the 'innovation' dimension, and localized specializations in industrial and distribution activities are positive. Negatively related to productivity growth are the initial productivity level, sectoral variety and the 'R&D' dimension. The sum of these outcomes indicate that specialization- and (employment) density based hypotheses of local economic growth are more relevant for the Dutch municipal data than variety-based hypotheses (compare Van Oort 2004). As a central economic indicator of economic performance, productivity (the amount of added value per full time equivalent employee) plays a important role in regional economic policy. We observe that the intensity of 'knowledge workers' and 'innovation' co-locates with productivity growth – but 'R&D' is not. R&D even appears to have a negative effect on productivity growth at the local level. This surprising result might have technical reasons (recall that R&D is measured in 2002 instead of the base-year 1996) or theoretical reasons. For instance, due to the fact that that not every R&D effort results in a productivity gain as the outcome of the 'trail and error' process of R&D and its valorization in new products. Also, the valorization of R&D investments can be in other countries in the case of multinationals, like Philips (Van Leeuwen and Van de Wiel 2003). Still, it is not certain that these aspects are exhaustive explanations for the negative coefficient in the models. Further (micro-level) research should be headed to this.

The overall conclusion is that high R&D-levels are not a sufficient growth condition for economic growth in urban clusters - the 'knowledge workers' and 'innovation' dimensions are significantly better linked to localized economic growth in the Netherlands. This questions the recent stress on R&D as knowledge-economic trigger by Dutch (and other European) governments. The way how firms innovate (introduce new products and services to the market) and how knowledge workers act in economic processes (by a high level of ICT usage, a high level of education and a high level of communicative skills) is more connected to the 'soft' side of the knowledge economy as opposed to the 'hard' technological side. The coefficients on the specialization and diversity variables indicate that locally specialized contexts are related to economic growth. A localized production structure with relatively more than average producer services enhances employment growth, while overrepresentation of industrial and distribution activities fosters average productivity growth. Diversity retards growth. Urban growth in clusters is more generally fed by the presence of innovative and flexible firms that specialize in knowledge workers characteristics.

3.5 Conclusions

In this paper we contributed to the longstanding discussion on the role of knowledge to economic growth in a spatial context. We observe that in adopting the European policy strategy towards a competitive knowledge economy, The Netherlands is – as most European countries - mainly oriented towards industrial, technological factors. The policy focus is on R&D specialized regions in their spatial economic strategies. We placed the knowledge economy in a broader perspective. Based on the knowledge economy literature, we valued complementary indicators: the successful introduction of new products and services to the market (innovation) and indicators of skills of employees: 'knowledge workers'. Using econometric analysis, we related the three factors 'R&D', 'innovation' and 'knowledge workers' to regional economic growth. We conclude that the factors 'innovation' and 'knowledge workers' are more profoundly related to urban employment and productivity growth than the R&D-factor. Focusing on other agglomeration factors, localized clusters of producer services (for employment growth) and of industrial and distribution activities (for productivity growth) contribute to economic performance of cities. Sectoral diversity instead, is negatively related to urban economic growth. Finally, we suggest that urban research and policymakers should preferably take all three knowledge economic factors (knowledge workers, innovation and R&D) into account when determining economic potentials of cities.

Appendix 3.1
Indicators of the Dutch knowledge economy

In this paper we introduce eight indicators of the Dutch knowledge economy (Raspe et al. 2004). All indicators are related to the location of firms (establishments). An important source of data is the LISA database (Landelijk Informatiesysteem Arbeidsplaatsen) that contains for 1996-2003 all establishments in the Netherlands (over 800,000), the type of economic activity (by NACE codes) and the number of employed persons. This dataset is the basis of our analysis of the regional economic structure of regions (aggregated to the level of municipalities). To construct the local indicators of the knowledge economy, we use statistics (national and regional, for instance on the level of provinces) that have a large sectoral detail that we use to regionalize the data. This appendix provides an empirical explanation of the eight indicators on the municipal level (n=496). All standardized indicators are visualized as standardized scores in figure 3.6, with mapping boundaries < -0.85, -0.85_-0.25, -0.25_+0.25, +0.25_+0.85, > +0.85).

Educational level
The average educational level of employment is calculated as the weighted sum of three levels of education: high (university and higher vocational education), middle (intermediate vocational education, higher general secondary education and pre-university education) and low (lower general secondary education and lower vocational education), respectively with the weights 3, 2 and 1. The three levels are measured as the total employment of an educational level in a sector (two digit NACE code). For every sector an average educational level, varying between 1 and 3, is estimated. To calculate the regional educational level we multiplied the average educational level per sector with the number of jobs in that sector, divided by the total number of jobs in the region (municipalities n = 496).

ICT-sensitivity
The indicator of ICT-sensitivity is the number of computers (and terminals) per job in industries in a municipality. First we computed the number of computers and terminals on the level of sectors (two digit NACE code, Automation Statistics Survey, Statistics Netherlands). Then we constructed an ICT-index per sector by dividing the number of computers and terminals by the number of jobs in a sector. In a third step the ICT-index is linked to the sectoral structure of the employment of the regions (municipalities, based on the LISA database).

Communicative skills
Based on Van der Laan (2000), we use as an indicator for social capital the relative overrepresentation of the number of employees specialized in communicative and information processing skills. The basic theoretical focus for this indicator stems from the 'model of persuasion' by McCloskey and Klamer (1995), in which economic transactions are not only based on market prizes and forces but also on persuasion and information judgment as well. In a growing number of jobs the importance of intense communication with others is fundamental in the persuasion of ideas or points of view. Especially concerning knowledge intensive jobs in science and consultancy. Maintaining and extending the position of trust in the relationship between the selling party and their customers plays a crucial role. Of all 1211 types of jobs (occupations) in the Standardized Jobs Classification (SBC'92, Statistics Netherlands) an inventory of specific skills based on a list of function descriptions (ARVO, 1989) is made. Eleven job qualifications resulted as clusters

of skills. Five skills are selected as mainly based on persuasion: [1] management, which contains policymaking, [2] verbal activities, which needs skills of oral and written reproduction of thoughts and feelings, [3] artificial activities, which demands expressive and aesthetic design, [4] service related activities, aimed at service to persons, and [5] activities that needs persuasion power in direct contacts. These five skills are linked to industrial composition. In a first step all occupations were scored in the matter they use one of the defined skills. An index is per sector is calculated, between zero and one. A score of zero means that no single person in a sector works in persuasive occupations. A score of 1 means everybody in a sector works in persuasive occupations. The scores per sector are linked to the LISA database (all individual establishment by sector and size of the employment in the Netherlands).

Creative economy

The indicator creative economy is the amount of creative jobs in the total jobs of a region. The selection of creative jobs is based on the symbolic meaning of the products and services (Manshanden et al. 2004), resulting in a list of creative sectors (4 digit NACE codes, Rev. 1.1, 2002). The focus is on the creation and production of creative goods and services, reproduction and distribution (see table 3.5):

Table 3.5 Creative economy by NACE codes

Arts		**Cultural Industries**		**Applied creative production**	
92.31	Artistic and literary creation and interpretation	22.11	Publishing of books	74.20	Architectural and engineering activities and related technical consultancy (Excl technical design civil engineering, electro. technical, machinery)
92.32	Operation of arts facilities (excl Theaters etc and event halls)	22.12	Publishing of newspapers	74.40	Advertising
92.52	Museums activities and preservation of historical sites and buildings (excl preservation of national monuments and historic buildings)	22.13	Publishing of journals and periodicals	74.87	Interior, fashion design
		22.14	Publishing of sound recordings		
		22.15	Other publishing		
		92.40	News agency activities		
		92.34	Other entertainment activities n.e.c.		
		74.81	Photographic activities		
		92.11	Motion picture and video production		
		92.20	Radio and television activities		
		92.13	Motion picture projection		

Innovation (technological and non-technological) and Research & Development

The innovation indicators are constructed as the number of employment of innovative firms in the total employment in a region (see De Bruijn 2004). This indicator is based on the European Community Information Survey (CIS '02), which is in the Netherlands carried out by Statistics Netherlands. Innovation is the result of innovation processes: the successful introduction of a new good or service on the market. We make a distinction in technological innovation: renewal of products and services or processes due to the development or application of new (to a firm) or recent technologies, and non-technological innovation: renewal not necessarily based on technological knowledge (for instance management, marketing or organizational renewal). The results of CIS '02 are on the level of provinces and 3 digit NACE codes, which are spatially redistributed by the LISA database (all individual establishment by sector and size of the employment in the Netherlands).

The R&D-indicator is the number of employment in R&D-jobs in the total employment in the region. This indicator is also based on the European Community Information Survey (CIS '02).

High-tech and medium-tech employment

The indicator high- and medium-tech is the amount of employment in a selection of high and medium-tech sectors in the total employment of a region. The selection of sectors is based on OECD (2003).

Figure 3.6 See pages 58 to 61, and table 3.6 page 62.

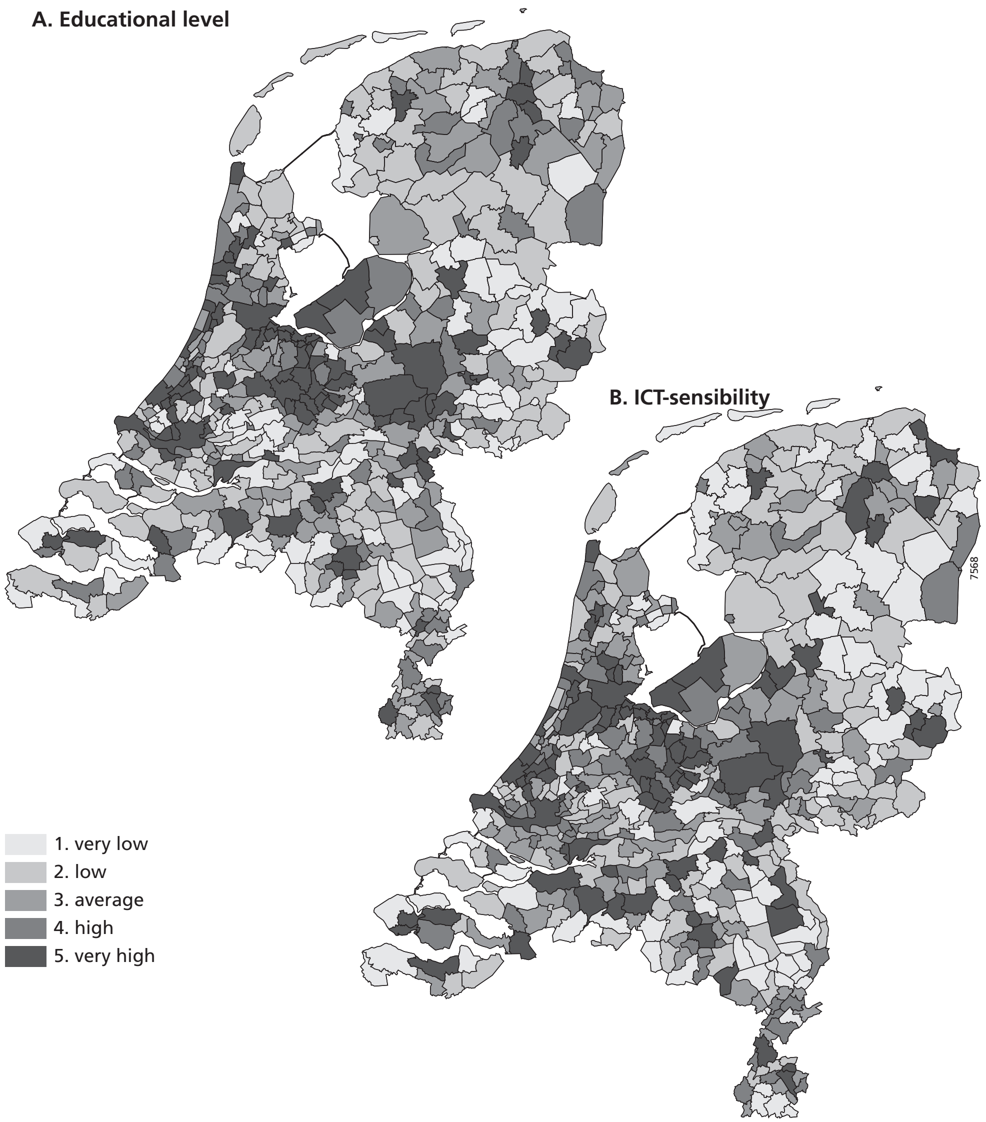

Figure 3.6 Spatial pattern of 8 knowledge indicators in the Netherlands (all 2002, municipalities)

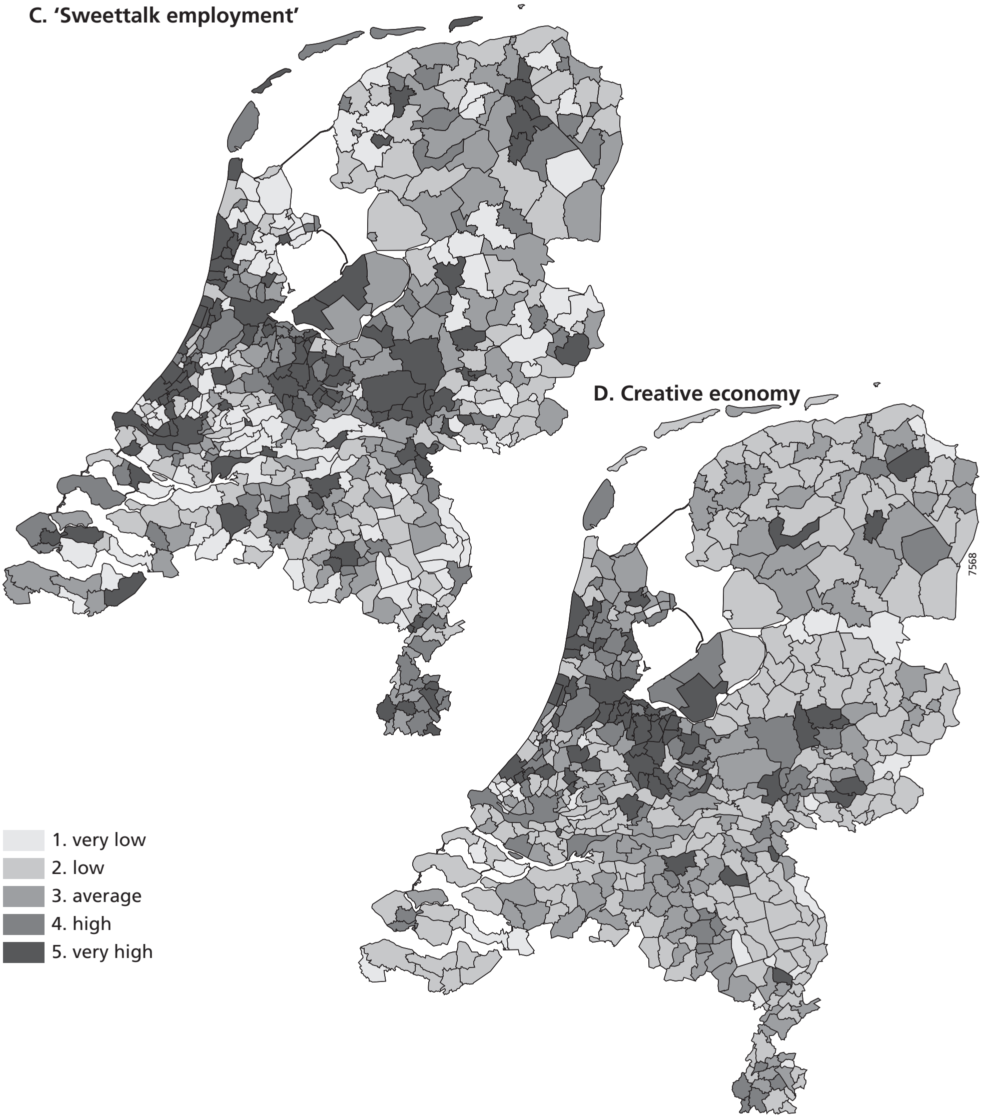

Figure 3.6 (continued)

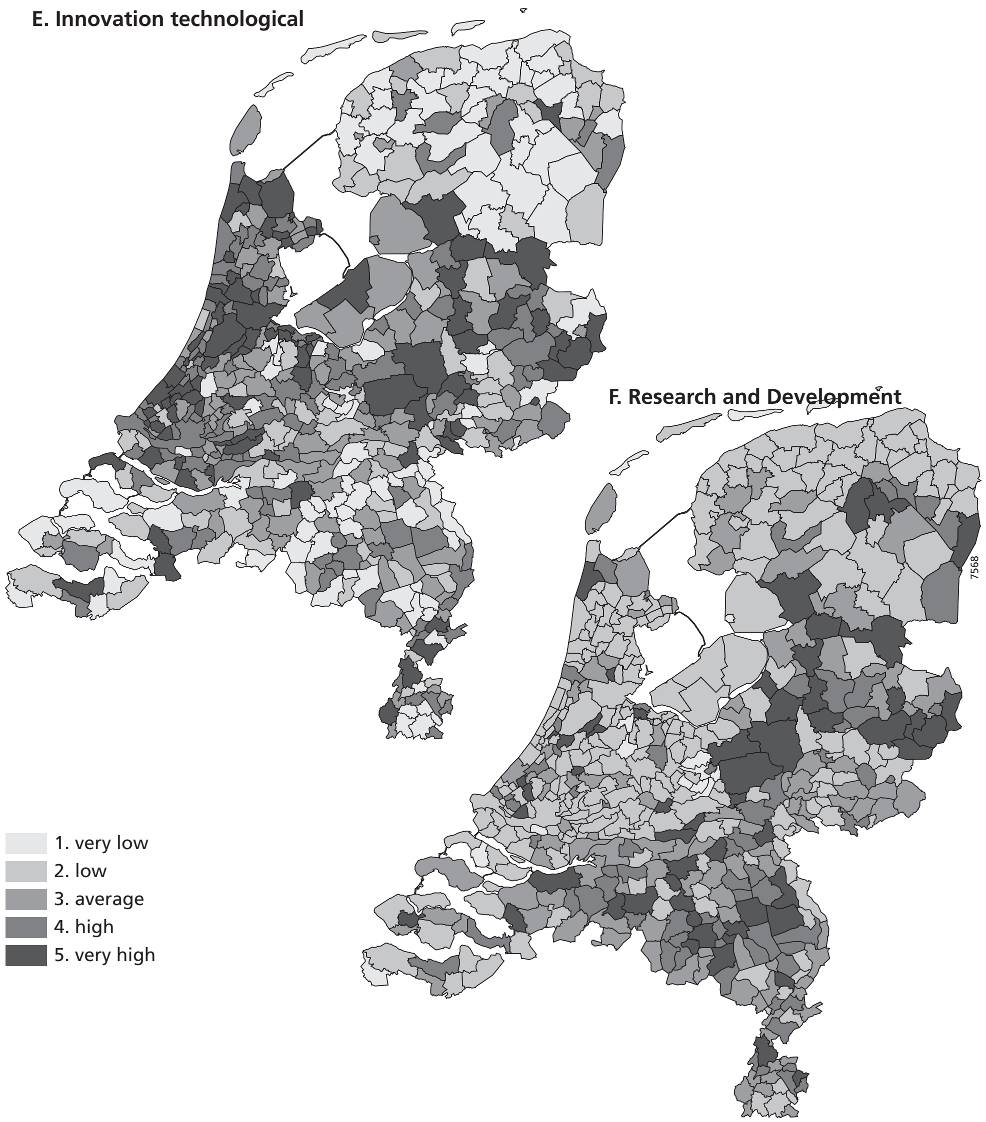

Figure 3.6 (continued)

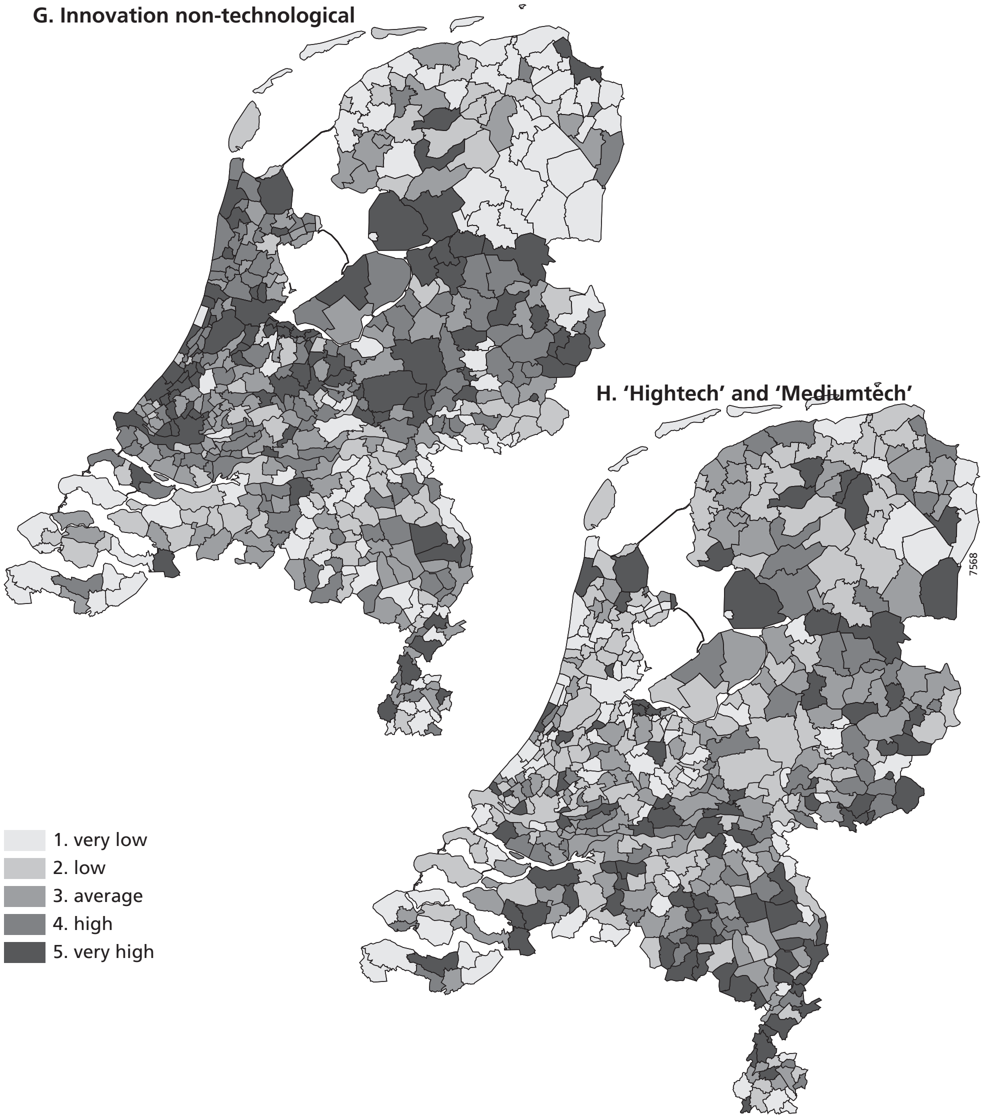

Figure 3.6 (continued)

Table 3.6 Correlation matrix of independent variables

	1. Fac1 'Knowledge workers'	**2. Fac2 'Innovation'**	**3. Fac3 'R&D'**	**4. LQ industrial activities (LOG)**	**5. LQ distribution (LOG)**	**6. LQ producer services (LOG)**	**7. Herfendahl index (LOG)**
1.	1	.000	.000	-.454(**)	-.508(**)	.451(**)	.136(**)
2.	.000	1	.000	.101(*)	.024	.213(**)	-.005
3.	.000	.000	1	.469(**)	-.174(**)	-.052	-.286(**)
4.	-.454(**)	.101(*)	.469(**)	1	.054	-.344(**)	-.524(**)
5.	-.508(**)	.024	-.174(**)	.054	1	.019	-.146(**)
6.	.451(**)	.213(**)	-.052	-.344(**)	.019	1	-.126(**)
7.	.136(**)	-.005	-.286(**)	-.524(**)	-.146(**)	-.126(**)	1
8.	.526(**)	.347(**)	.093(*)	-.068	-.155(**)	.365(**)	-.031
9.	-.159(**)	-.095(*)	-.056	.055	.158(**)	.051	-.109(*)
10.	-.091(*)	-.047	.106(*)	.150(**)	.098(*)	.063	-.134(**)
11.	-.178(**)	.002	.003	.090(*)	.079	-.124(**)	-.026
12.	-.117(**)	-.129(**)	.147(**)	.207(**)	-.190(**)	-.206(**)	-.090(*)
13.	.521(**)	.311(**)	.284(**)	.088	-.232(**)	.322(**)	-.248(**)
14.	.241(**)	.200(**)	.056	.063	-.018	.240(**)	-.157(**)

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 3.6 Continued

8. Population density (LOG)	9. Investment level (LOG)	10. Wage level (LOG)	11. Supply business areas growth (LOG)	12. Dummy border regions	13. Employment level 1996 (LOG)	14. Productivity level 1996 (LOG)
.526(**)	-.159(**)	-.091(*)	-.178(**)	-.117(**)	.521(**)	.241(**)
.347(**)	-.095(*)	-.047	.002	-.129(**)	.311(**)	.200(**)
.093(*)	-.056	.106(*)	.003	.147(**)	.284(**)	.056
-.068	.055	.150(**)	.090(*)	.207(**)	.088	.063
-.155(**)	.158(**)	.098(*)	.079	-.190(**)	-.232(**)	-.018
.365(**)	.051	.063	-.124(**)	-.206(**)	.322(**)	.240(**)
-.031	-.109(*)	-.134(**)	-.026	-.090(*)	-.248(**)	-.157(**)
1	-.182(**)	-.240(**)	-.121(**)	-.114(*)	.607(**)	.343(**)
-.182(**)	1	.142(**)	-.019	-.084	-.024	.010
-.240(**)	.142(**)	1	-.081	-.012	-.128(**)	.050
-.121(**)	-.019	-.081	1	-.015	-.070	-.210(**)
-.114(*)	-.084	-.012	-.015	1	-.049	-.053
.607(**)	-.024	-.128(**)	-.070	-.049	1	.305(**)
.343(**)	.010	.050	-.210(**)	-.053	.305(**)	1

4 Firm growth and localized knowledge externalities[23]

Abstract
A lively debate in the literature focuses on the potential for a firm to profit from a location in a knowledge intensive context. If localized knowledge spillovers are important, firms tend to locate in proximity to capitalize on the knowledge stock of each other and knowledge institutions. We apply econometric modeling techniques that enable us to model firm level survival and (subsequent) employment growth simultaneously with different types of locally endowed knowledge externalities. We define the latent contextual concept of 'knowledge economy' using three manifest (measurable) dimensions. Based on the knowledge economy literature, we not only focus on technological externalities ('R&D'), but we value complementary indicators like the successful introduction of new products and services to the market ('innovation') and indicators of skills of employees ('knowledge workers'). The latter contains the use of ICT, educational level of the workforce, and communicative and creative skills. We use employment data for manufacturing and business services firms stemming from a micro dataset of approximately 62,000 firms in the Netherlands in the period 2001-2006. We conclude on the size and knowledge related composition of the contextual effects, in which the innovation dimension turns out to be most robustly related to firm-level economic growth.

4.1 Introduction

Due to the substantial theoretical foundation of the role of knowledge in modern growth theory (Romer 1986, Lucas 1988), the opinion is that 'knowledge' is an explicit and crucial factor for generating sustained economic growth in Western economies (Audretsch et al. 2006). Within this theorizing, knowledge spillovers are considered a key element in these new growth theory models and form a mechanism in firm-external economies (Koo 2005). According to this view, individual firms produce (technological) knowledge. At first, this is firm internal; afterwards, it might spill over to the rest of the economy as it can be copied at almost no cost by other firms. It might even become social knowledge, acting as an external effect in enhancing the productivity of all firms. With the spillover effect, an aggregate production function with otherwise constant or decreasing returns to scale may exhibit increasing returns to scale, allowing sustained long-run growth. An implication of this view is that a firm, not able to innovate on its own, can benefit from the research findings of firms working along similar lines (Sena 2004).

Besides researchers in growth economies, the concept of knowledge spillovers brings together researchers in the field of industrial, innovation and entrepreneurship economics, as well as geographers and regional scientists. Contrary to the new growth theory models both fields stress that one should not assume that spillovers are automatic and costless (Acs and Plummer 2005,

23 Raspe, O and F.G. van Oort (2008) Firm growth and localized knowledge externalities, The Journal of Regional Analysis and Policy, 38(2): 100-116, Copyright © MCRSA.

Grosmann and Helpman 1991). Instead, especially the geographical and regional economics literature on knowledge spillovers confronts us with the fact that despite its public good properties, knowledge does not diffuse instantaneously to production facilities around the world (Döring and Schnellenbach 2006). In this literature there is a tradition for analyzing the local advantages of proximity or agglomeration, questioning whether regional economic growth is higher in regions where more organizations or knowledge are concentrated (Glaeser et al. 2002, Feldman and Audretsch 1999). Also the 'territorial innovation' literature – elaborated in different concepts like clusters (Porter 1990), industrial districts (Markusen 1996, Kaufmann and Tödtling 2000), regional innovation systems (Carlsson 2003), innovative milieu (Camagni 1991), and learning regions (Morgan 1997) – suggests that learning processes take place at the local and regional level, and that this is crucial for the creation and acceptance of innovation. In this literature, arguments of proximity, face-to-face interaction, knowledge tacit-ness, the 'stickiness of information', long-term trust-based relationships between firms, labor market mobility, and spin-offs all point to advantages of regions and cities in explaining economic growth due to knowledge spillovers (McCann and Simonen 2005).

If knowledge spillovers are important for growth, they will influence firms' location decisions. In particular, when knowledge is not easily exchanged from a distance and spills over locally, firms tend to locate in proximity to capitalize on the knowledge stock in neighboring firms (Koo 2005). While the empirical evidence about the linkages between agglomerations and growth focus at regional and local analysis, the relationship should actually and most profoundly hold at the micro or firm level. But, in fact, very little is known about the locational impact on firm performance, as measured in terms of individual growth. As studies on entrepreneurship and industrial dynamics often overlook the role of location (Parker 2005), in geography the firm has long been neglected (Maskell 2001, Taylor and Asheim 2002, Harrison et al. 1996). The firm and the geographical cluster in innovation and learning processes have typically been studied separately (Mariani 2004, Koo 2005), and only few attempts have been made to relate a firm's innovativeness and performance to regional variables, so as to provide a clear distinction between firm- and region-specific effects (Beugelsdijk 2006). Audretsch and Dohse (2007) indicate that the reasons for this omission are both conceptual and empirical in nature. At the conceptual level, there are hardly any models that link the performance of individual firms to regional (knowledge and human capital) characteristics. At the empirical level, analyzing firm growth (in a spatial context) requires longitudinal data at the establishment or enterprise level, which are often not available (Acs and Armington 2004a).

In this paper we contribute to the discussion on spatial and firm level growth conceptualizations by linking the performance of firms, measured in terms of employment growth, to the external knowledge characteristics of geographic locations. We focus on factors that are external to the firm. The initial process of knowledge creation inside the firm is not the main focus of analysis in the paper.

The paper is organized as follows. The next section deals with the question why it is important to take both firm-specific and geographical determinants of firm growth simultaneously into account. Section 4.3 introduces three independent regional knowledge factors ('R&D', 'innovation', and 'knowledge workers') and builds up to regional patterns of these in the Dutch knowledge economy. Section 4.4 discusses these contextual (regional) knowledge variables together with firm-level characteristics, which are combined in the econometric estimations of firm survival and growth in section 4.5. The last section presents conclusions.

4.2 Firm level and entrepreneurial heterogeneity

In the economic geographical and regional economic literature, 'proximity' is not the only factor which seems to matter for firm's external economies, so does type of spatial context. Local agglomeration externalities vary over regions, as factors affecting agglomeration forces, like labor mobility and spatial and economic policies, differ from one region to another. Another relevant context that might be region-specific is that of industry-structure: firms in some industries benefit more from geographical concentration than their counterparts in other industries (Combes et al. 2004, Henderson 2003).

In most empirical models, regions or agglomerations and their knowledge spillover potential are treated as a location-specific externality that can occur within the same industry (localization economies, or so-called MAR-spillovers coined after three pioneering contributors, Marshall (1890), Arrow (1962) and Romer (1986)) or across all industries as a consequence of the scale of a city or region (urbanization economies, also known as Jacobs' externalities after Jacobs (1969)). The recent spatial spillover literature provides us with a vast accumulation of empirical research on the issue of these agglomeration externalities. Whether diversity or specialization of economic activity better promotes technological change and subsequent economic growth has been the subject of a lively debate in the economic literature (Feldman & Audretsch 1999, Frenken et al. 2006), also including the contribution of Trippl and Tödling in this issue of JRAP. Both types of spillover assume proximity to be crucial for economic growth, but define externalities stemming from knowledge only implicitly. We define the knowledge economy and its composing elements more structurally and treat them as localized knowledge externalities (inhabiting both specialization and variety characteristics).

However, firms vary widely in their specific characteristics and organizational behavior. If there are systematic differences in firm location choices based on these firm characteristics such that more productive or innovative firms tend to locate more often in cities and agglomerations, regional analyses might be biased (Koo and Lall 2007). Regional analyses will overestimate the importance of agglomeration economies since firms that started in or moved into the agglomerated region might have a higher than average firm-level growth (Baldwin and Okubo 2006). A significant portion of performance of firms in knowledge intensive regions may be attributable to firm heterogeneity, and if such firm level differences are not controlled for, the effects of localized knowledge externalities can be exaggerated. A range of firm-specific variables needs to be included in the analyses to minimize unobserved firm-specific heterogeneity and to provide a proper test of the effect of the regional environment on firm growth (Mariani 2004).

An analysis with a stronger micro level foundation, in which systematic differences in performance of firms located in specific regions may arise not only from spatial factors (in our case knowledge externalities) but also from firms' specific characteristics, gives in to objections that blurring macro level evidence with micro level arguments may lead to an ecological fallacy (Robinson 1950). In economic geography a real micro theoretical foundation that spells out how the firm behaves and performs in space when competing in markets, is absent (Maskell 2001, Taylor and Asheim 2002). There is a need for a stronger theoretical foundation and empirical testing, no longer treating firms as black boxes and taking geography properly into account. In that view, the firm or entrepreneur is not just a lonely actor pursuing an individual vision, but also a social agent situated within a wider system of production that can be represented as an actual and latent grid of interactions and opportunities in organizational and geographical space (Scott 2004). Clearly, embeddedness, contexts and networks matter for firm performance, but as Stam (2007) indicates, the issues of how they matter, under which circumstances, to what extent, and in which ways are difficult to tackle. The meta-theoretical foundations for a contextual approach on entrepreneurship can be summarized in the statement that knowledge arises from categories of information that people exploit in interaction with their real and socially constructed physical and socio-cultural environment. In that external knowledge view geography is not simply a passive frame of reference, but should be an active ingredient in economic development and growth.

4.2.1 A firm level interactionist approach

An interactionist approach, taking both firm specific and regional factors into account, means that the firm should be treated as the central actor. There is a long tradition in what is called 'the theory of the firm'. Early pioneering work of Coase (1937) is based on a transaction cost or contractual approach (Williamson 1985). Later on, stimulated by the work of Penrose (1959), more evolutionary approaches developed in a competence view of the firm (Nelson, 1994). The competence-based approach emphasizes the importance of path-dependent, group-based, firm-level, and largely tacit and socially produced and reproduced knowledge – that is competencies – (Foss 1998). The main reaction on the contractual perspective is that the firm as a repository of tacit knowledge is neglected in the contractual perspectives (Foss 1993). It is argued that the competence perspective is not only applicable to an understanding of the sources of firms' competitive advantage, but may also be applied to the issues of the existence and the boundaries of the firm. Particularly this resource-based or competence-based view of the firm provides a coherent theoretical framework, to be further developed in an interactionist approach of the firm in its spatial context (Maskell 2001). The main advantages are the explicit treatment of knowledge in production (including a treatment of both the endogeneity and path-dependency of this knowledge) and the explicit recognition of genuine uncertainty lacking knowledge and the dynamics that give rise to this. This can be placed in the debate of absorptive capacity: knowledge is unlikely to spill over between firms simply because they are located near one another, but will only do so if they are able to identify, exploit and integrate external knowledge into their own knowledge base. In other words, a certain level of absorptive capacity is required (Cohen and Levinthal 1990). The explicit recognition of uncertainty fits in the debate of seeking business opportunities within uncertain contexts and the advantages to grasp opportunities proximate to external knowledge sources.

The underlying conditions for sustained competitive advantages of firms define the way in which firms acquire or rent tangible or intangible resources (both technical, economic or organizational) and combine them in building firm-specific competencies. Firms survive and thrive, not because of exogenous market size or industry characteristics, but primarily because of factors within themselves (Maskell 2001). As firms working in a competitive environment repeatedly apply their unique resources (or their unique combinations of familiar resources) to commercial tasks, they learn from their successes and accumulate further assets. The firm therefore is a generator and processor of knowledge, and its learning capabilities are embedded in the routines that characterize its organization. Those learning capabilities might be enhanced in specific localities where otherwise non-transferable tacit knowledge and experiential assets are available through face-to-face contact (Taylor and Asheim 2001). This socioeconomic perspective offers a better framework for determining the dynamic role of space in shaping firms.

Knowledge creation and entrepreneurial learning are strongly put to the fore as the most important strategic activities of the firm, and spillovers of knowledge are important in generating innovative output (Parker 2005). Able entrepreneurs survive and grow, while the less able (or unlucky) exit the market. New scientific and technological knowledge is often an important source of entrepreneurial opportunities. Acs et al. (2004) introduce the entrepreneur as a conduit for transforming new knowledge into new economically valuable business opportunities. New knowledge and ideas created in one context, such as a research laboratory in a large corporation or a university, but left uncommercialized, generates entrepreneurial opportunities. A main mechanism for recognizing new opportunities and actually implementing them by starting new economic activities involves knowledge spillovers (Audretsch et al. 2006). Entrepreneurship can take shape by new firm formation, start-ups and spin-offs, but also by incorporating business opportunities in incumbent firms.

In this paper we focus on firm survival and growth and focus on the role of knowledge intensive locations. Following earlier findings in organizational ecology and industrial organization literature (Jovanovic 1982, Caroll and Hannan 2000), we define firm size and firm age as important individual (firm-level) determinants of growth. It is argued that they largely determine firms' resource base and competences. Small firms have to overcome costs disadvantages contrary to larger firms. Due to 'internal economies of scale', causing a reduction in per unit costs over the number of units produced, efficiency advantages and hence growth potential emerge from larger firm sizes. A debate centers around Gibrat's law – stating that firm growth rates are distributed independently of firm size. The empirical evidence on this is mixed (Sutton 1997). A considerable number of studies support the view that large firms are less likely to achieve good growth performances because of the ossification of routines and learning processes. It is especially important to add the firm's age to the growth-size relationship (Jovanovic 1982). The stylized findings give indications that age has a negative effect on firm-level growth, suggesting that firm growth tends to decline as the firm evolves over its life cycle (Audretsch and Dohse 2007). Firms have different efficiencies and hence different cost levels, and firms learn form their own experience. Firms can start small and suffer from scale disadvantages. Successful small firms grow and become more efficient (i.e. reduce their costs), while the unsuccessful ones remain small or may be forced to exit the industry. Evans (1987) argues that this theory generally implies that growth declines with age.

Besides size and age, the type of economic activities is also important for firm growth. Often industry fixed industry effects are introduced, capturing various technology and knowledge dimensions (Teece 1986, Breschi et al. 1996) such as technological opportunity, appropriability regimes, or the emergence of dominant designs along the technology life cycle.

As in geography the firm has long not gained the attention it deserved, in entrepreneurial studies the locational aspects have long been overlooked (Audretsch and Dohse 2007). Controlling for firm-specific characteristics we focus on the correlation of external knowledge sources with firm-level economic development and growth (Scott 2004). No consensus is reached in the literature on the spatial range that can be attributed to knowledge spillovers (Döring and Schnellenbach 2006). Lucas (1993) emphasizes that the most natural context in which to understand the mechanics of economic growth is in those areas where the compact nature of the geographic unit facilitates communication – cities. Also Feldman and Audretsch (1999), Glaeser et al. (2002) and Duranton and Puga (2003) stress this role of cities and agglomerations. Cities bring together a large number of people, thus facilitating face-to-face contacts and learning opportunities. In our study we therefore analyze the knowledge economy at the scale of Dutch municipalities. Municipalities in the Netherlands are the closest scale to cities. A constellation of central and suburban municipalities forms an agglomeration.

4.2.2 Firm growth

In this paper we take employment growth as a performance indicator. It is good to notice that many firms besides staying in business have profits (or the maximization from that) as their goal, which can lead to a growth strategy in output and employment.
With respect to firm growth, Delmar et al. (2003) state that the use of sales and employment measures are the most widely used in empirical research. They notice the emerging consensus that if only one indicator is to be chosen as a measure of firm growth, the most preferred measure would be sales. But they also address some pitfalls. Sales are not the perfect indicator of growth for all purposes. Sales are sensitive to inflation and currency exchange rates, while employment is not. And it is not always true that more sales lead to growth processes. For high-technology start-ups and start-ups of new activities in established firms, it is possible that assets and employment will grow before any sale will occur. Arguments are offered for employment as a much more direct indicator of organizational complexity than sales, and this indicator may be preferable if the focus of interest is on the managerial implications of growth. The same line of reasoning about the value of employment-based measures of growth applies for resource and knowledge-based views. If firms are viewed as bundles of resources, a growth analysis ought to focus on the accumulation of resources, such as employees. Furthermore, when a more macro-oriented interest in job creation is the rationale for the study, measuring growth in employment seems to be the natural choice. An obvious drawback of using employment as a growth indicator is that this measure is affected by labor productivity increases, machine-for-man substitution, degree of integration, and other make-or-buy decisions. A firm can grow considerably in output and assets without growth in employment.

Also, employment is often used as performance indicator on the firm level in innovation literature (Brouwer et al. 1993, Audretsch 1995). Besides the fact that employment growth provides an indicator of firm assets (human resources being among the most important assets of a (new) firm), there are additional arguments. Innovations that lead to new products and services (more radical innovation) in particular will lead to economic growth by developing new economic activities and new sectors, which in turn will produce employment growth. Incremental innovations more often make firms perform more efficiently, leading to a higher output per employee and thus a higher productivity (Saviotti and Pyka 2004). This means that fluctuations in staff size is a conservative measure for investigating the instability of growth, compared to more rapidly changing figures as sales (or productivity) of capital valuation.

In our study we take employment as a growth indicator. In addition to the earlier arguments, this matches our comparison with the regional growth literature best, since regional studies on knowledge spillovers, for example by Glaeser et al. (1992), Henderson et al. (1995) and Simon (1995) – and a large number of studies following this line of reasoning (for an overview, see De Groot et al. (2007)) – have used employment growth (in industries) as a leading indicator for economic growth. It is important to notice that each indicator has a different meaning and theoretical background. It would be advantageous to explore the use of different growth measures in a study of firm growth when these are available, especially because the complexity of employment and productivity growth on the micro level strongly differs from the 'stylized facts' on the macro level. Where in macro studies a rising productivity and decreasing employment (and vise versa) are inextricably linked, argued by technological progress, or downsizing, Baily et al. (1996) however argue that it is misleading to draw inferences from aggregated data to characterize what has happened at the micro level of individual plants. There is a substantial heterogeneity among plants and industries and at the plant level complex processes of employment, output and productivity growth come together. Within this complexity there are potential differences by industry, firm size, and region.

4.3 The knowledge economy in urban space

The recent interest in the knowledge economy is embedded in a long tradition. The knowledge economy is usually understood as an economy in which the production factors labor and capital are aimed at the development and application of new technologies (OECD 1996). This definition falls short in the sense that the ultimate goal of the knowledge economy is taken to be the application of new technologies as such, while, in fact, this application is instrumental to the goals of innovation and economic (productivity) growth. Since its introduction, many theoretical and empirical contributions have therefore refined and broadened the concept. We distilled (measurable) indicators that are relevant for firm level and contextual growth models from this literature (Raspe and Van Oort 2006). In this context, it is also necessary to conceptualize knowledge.

We define knowledge as the ability to recognize and solve problems, by collecting, selecting and interpreting relevant information. Hence, a basic feature of the knowledge economy is the use of knowledge in interrelationships among market actors to produce goods and services, from the first idea to final products. Lucas (1988) and Mathur (1999) argue that human capital, particularly education, is a crucial feature of the knowledge economy. A well-educated workforce has ample opportunities to absorb and use information. In measuring the localized knowledge economy, we therefore use the average educational level of the working population per municipality as a first indicator. Florida (2002), though, identifies creative capital embodied in knowledge workers and artists as a major indicator of the knowledge economy. The difference between human and creative capital is that the 'creative class' (as Florida labels it) does not necessarily needs to have a high educational level in order to create added value. In addition to direct productivity effects produced by knowledge workers, Florida emphasizes indirect growth effects from consumption by the creative class in the amenity-rich urban environments they live in. Since data on the creative class itself is not available, we use a proxy, i.e. the density of creative industries, as a second knowledge economy indicator. The literature on the knowledge economy also emphasizes two indicators that reflect accessibility and transfer of knowledge. In particular, Drennan (2002) and Black and Lynch (2001) analyze the growth potentials of firms related to an increased accessibility of information through the adoption of information and communication technologies (ICT). Hence, we take ICT density (measured by computer usage per employee per industry) as a third indicator. Cooke and Morgan (1997) and Clement et al. (1998) identify social, cultural and communicative capital as sources of employment growth. We measure this variable via the classification of occupations according to the degree of communicative skills needed for interaction (as suggested by McCloskey and Klamer, (1995)). We define a sectorally weighted average degree of communication skills as a fourth indicator.

Our definition of the locally defined knowledge economy also addresses technical and production oriented aspects. As shown by amongst others Black (2004), most attention has traditionally been paid to research and development (R&D). We use the sectorally weighted share of R&D employees as a fifth indicator. Additionally, Cortright and Mayer (2001) emphasize the role of high- and medium tech firms as indicators of the knowledge economy and drivers of economic and employment growth. Besides R&D-intensity, the OECD argues that high- and medium tech firms are characterized by their export intensity. We take the density of these industries as sectorally defined by the OECD (2003) relative to the total population of firms, as a sixth indicator. Finally, innovation is generally regarded as the most important driver of economic and employment growth. Several indicators of innovation exist, e.g. new product announcements, publications, patents and firm self-ratings (Jaffe and Trajtenberg 2002). In this paper we use firm self-ratings of new products and processes (as expressed by firms in the Third Community Innovation Survey for the Netherlands). We distinguish between technical and non-technical innovations. While technical innovations relate to new products and production processes, non-technical innovations concern management, organization and services. Both aspects are taken into account when estimating the proportion of innovative firms in a municipality. They are our seventh and eighth indicators.

These variables are indicators of underlying latent variables, and are therefore strongly correlated. Regions specialized in ICT-intensive activities usually also are characterized by a highly educated labor force. And R&D-intensive regions usually also contain many high- and medium tech firms. Direct inclusion of the indicators would thus lead to multicollinearity and hence an increase of the estimated variances of the estimators of their coefficients so that one might be led to drop some of the variables incorrectly from the productivity model. Therefore, we include three latent variables into the model rather than the indicators (Raspe and Van Oort 2006). The latent variables are related to their observable indicators via a (principal component) measurement model. We distinguish the following latent variables:

1. 'Knowledge workers' with indicators: ICT sensitivity, educational level, creative class, and communicative skills
2. 'R&D' with indicators: the density of high and medium tech firms and the share of R&D employees
3. 'Innovativeness' with indicators: technical and non-technical innovations.

Table 4.1 shows the factor scores for these principal components. Values in italics mark the loading of the indicators that are taken together in the three factors.

The spatial patterns of these three factors of the Dutch knowledge economy are presented in Figures 4.1a-c. From Figure 4.1a it follows that the knowledge workers component is concentrated in larger cities and regions in the Randstad region, the western economic core region of the country. This applies in particular to large cities like Amsterdam and Utrecht as well as their suburban

Table 4.1 Factor scores of principal components

Indicators:	**Factors:**		
	Factor 1 'Knowledge workers'	Factor 2 'Innovation'	Factor 3 'R&D'
ICT-sensitivity	*0.753*	0.365	0.268
Education level	*0.949*	0.164	0.044
Creative economy	*0.516*	0.024	-0.198
Communicative skills	*0.927*	0.040	-0.069
High-tech and medium-tech	-0.175	0.146	*0.840*
Research and Development	0.080	0.129	*0.836*
Innovation (technological)	0.130	*0.878*	0.246
Innovation (non-technological)	0.147	*0.914*	0.054

Source: Raspe and Van Oort (2006).

surroundings. Rural regions are lagging. The spatial distribution of the 'R&D' component (Figure 4.1b) is quite different from that of knowledge workers. R&D is concentrated in the southern and eastern regions of the country. These are regions with a strong industrial orientation (Van Oort 2004). The regions of Eindhoven (with Philips and ASML), Wageningen (technical university), Delft (technical university), and Dordrecht and Terneuzen (with the technologically oriented multinational firms Du Point and Dow Chemical) are the R&D hotspots in the Netherlands. Regarding the factor Innovation, Figure 4.1c shows that innovative firms are mainly concentrated in the western Randstad region of the Netherlands.

4.4 Research framework and variables

The previous section showed that within the Netherlands, a considerable spatial differentiation in knowledge intensities exists. To answer our research question – whether firm growth is related to these differences – we model firm growth at the micro level. We use the LISA database of all Dutch economic establishments (by activity code, and exact location, size and age). Although the dataset is longitudinal for the period 1999–2006, we analyze the growth in employment of firms in the period 2001–2006 because the year 2001 was unique with respect to the contextual (regional) knowledge indicators. Within this database we selected all firms in the basic activities of manufacturing and business services. These firms are not dependent on population density (consumers) for their locational choices, and knowledge is crucial for their functioning. We only analyzed establishments with more that one employee, since firms with one employee only are often non-active 'postbox' firms. Table 4.2 summarizes the total population of establishments in the period 2001–2006, aggregated into classes of age and size.

The variable AGE is the number of years the firm has been active since it entered the database. As we model growth in the period 2001–2006, we selected firms by their existence in 2001, and analyzed their path of survival and growth afterwards. For firms that entered the database in the period 1999–2006 we know the exact founding year. Establishments older than 1999 are marked as 'age older than 8' (compare Van Wissen 2000). Table 4.2 shows that for manufacturing firms

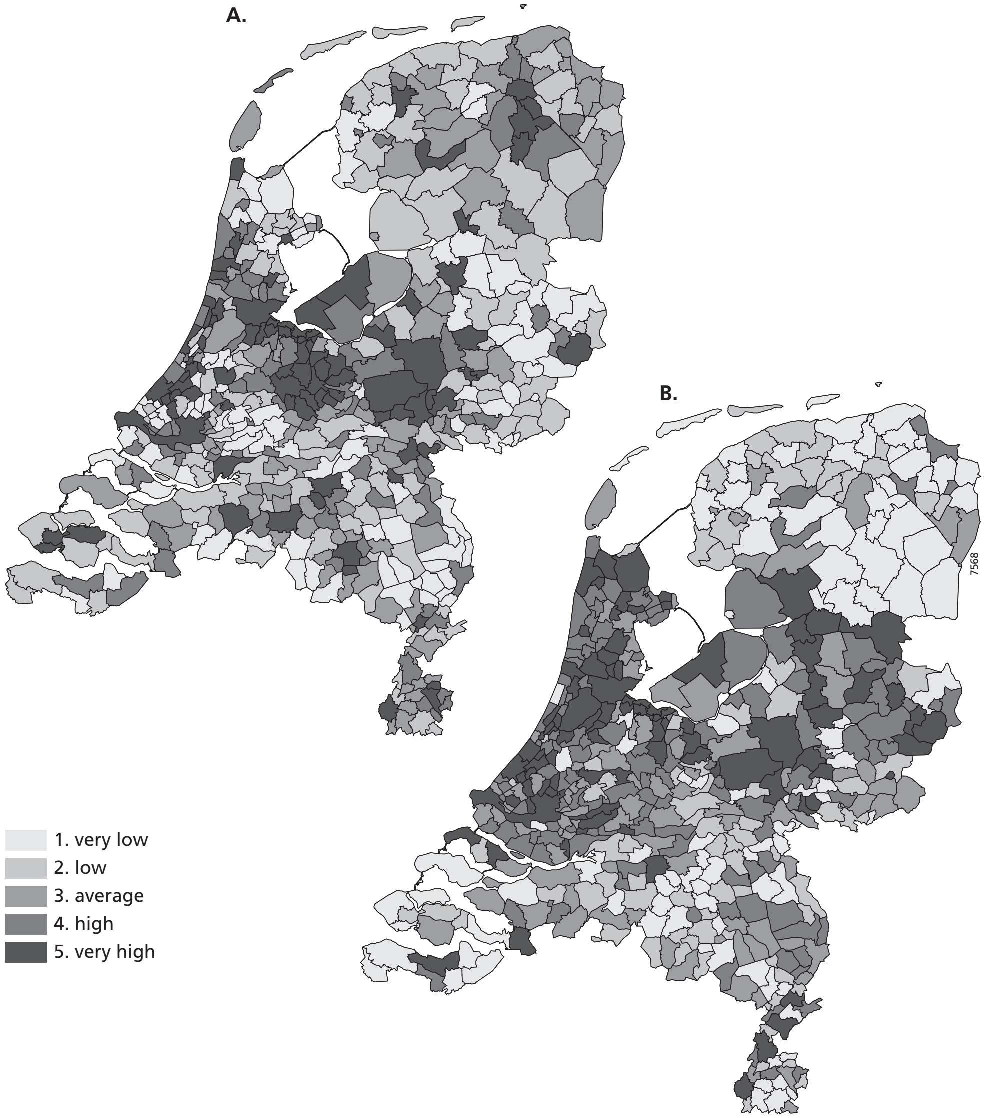

Figure 4.1a–c Spatial pattern of 1. 'Knowledge workers' (A), 2. 'Innovation' (B) and 3. 'R&D' (C)

almost 75 percent, and for business services approximately 60 percent are older than 8 years. Our hypothesis is that age is negatively related to the growth of a firm.

SIZE is defined on the basis of the number of jobs in firms in the year 2001. Table 4.2 shows that the research population consists of many small firms (2–10 jobs). For manufacturing approximately half of the firms have less than 10 employees. Business services are even more biased to small firms: 70 percent employ less that 10 people. Within the population of manufacturing firms there is also a larger share of large firms (more than 100 employees), compared to business services. Our hypothesis is that firm size is negatively related to employment growth. In relative terms it is more

C.

Table 4.2 Frequencies by size and age of the total population of firms

	Manufacturing	Business Services
	Frequency	Frequency
AGE 1	0.66%	2.14%
AGE 2	0.62%	2.30%
AGE 3	4.74%	7.59%
AGE 4	4.41%	6.36%
AGE 5	4.08%	5.56%
AGE 6	5.89%	9.10%
AGE 7	5.43%	7.87%
AGE 8 and more	74.16%	59.07%
SIZE 2-10	51.8%	70.3%
SIZE 10-25	22.7%	16.2%
SIZE 25-50	11.3%	6.6%
SIZE 50-100	6.8%	3.7%
SIZE >100	7.3%	3.2%
N	22.955	63.961

difficult for larger firms to grow compared to smaller. In many contributions (Evans 1987, Hall 1987, Audretsch and Dohse 2007) a non-linear relationship between size and growth is assumed.

Besides size and age, the type of economic activity of firms is also introduced, i.e. the industry (sector). There are large growth differences between different sectors, and firms within a sector usually gain from similar growth circumstances. Taking the industrial composition into account is also highly policy relevant. Many (national as well as local) governments focus on sectorally related growth policies. In this paper we related this to so-called key sectors defined by the Dutch Ministry of Economic Affairs (EZ 2005): economic sectors, technologies and networks in which the Dutch economy is supposed to excel on combinations of entrepreneurship and knowledge base. These key sectors are considered important for the Dutch international competitive position and growth potential. In reality, these sectors are not typically Dutch, as all modern economies try to excel in similar ones. To test for their supposed exaggerating growth potential, we include sector dummies for high-tech industries, chemistry, ICT, creative industries and financial services (see Appendix 4.2 for their NACE codes).

On the firm level, employment growth is defined as:

$$\Delta\, EMPLOYMENT_i = \ln\left(\frac{EMPLOYMENT_{it}}{EMPLOYMENT_{i(t-1)}}\right) \tag{4.1}$$

i = firm, t = year (we measure growth in 2001-2006, so t-1 is 2001)

Our knowledge intensive spatial contexts are taken from section 4.3: the knowledge workers (*KW*), innovation (*INN*) and Research and Development (*R&D*) dimensions. In the models we introduce a lagged effect in the relation between the firm's knowledge context and firm performance. As put forward by Henderson (2003), it is expected that it takes time for knowledge to spill over and get embedded in firms. We use a moving five year time lag by linking firm performance in the period 2001-2006 to variables in the industrial environment in (the beginning-of-period) 2001.

As we select all firms in the distinguished sectors that existed in 2001 and track their growth path until 2006, we face the problem of panel attrition by non-survival. Firms that do not survive do inhabit information on the missing dependent variable. Possible disturbance in the estimation of the growth coefficients related to this selection bias occurs when characteristics of non-survival are related to firm growth. We control for this selection bias by applying a two-step Heckman procedure: first a probit estimate of survival from the whole sample (survivors and non-survivors) is made and second a growth estimation for the selected sample of survivors using the Inverse Mill's ratio (*LAMBDA*) obtained from the first step is used as a correction factor (Heckman 1976). This ratio is a summarizing measure that reflects the effects of all unmeasured characteristics that are related to firm survival, and catches the part of the non-survivors effect which is related to growth. This means that the growth models are unconditional on survival. An important condition for this estimation procedure is that to avoid multicollinearity problems, the selection equation contains at least one variable that is not related to the dependent variable in the substantial (growth) equation. In our analysis we include the average number of bankruptcies per establishment on the regional level as an indicator of regional differences in the chance to survive. Because this indicator has no clear theoretical and empirical relation with individual firm employment growth but a clear relation with firm survival, this variable is used as an instrument (*INSTR*).

Appendix 4.1 shows the descriptive statistics of the dependent variable (employment growth) and the explaining firm level and context level variables (no partial correlations higher than 0.3 exist, except between size and size-squared). The mean value of firm growth indicates that on average manufacturing and business service employment growth is slightly negative. Part of the period of 2001-2006 suffered from recession with an employment decline. Appendix 4.1 also shows that the variable age has a minimum of six years and a maximum of eight years. The variable age therefore cannot be interpreted as that of the founding year of firms, but instead controls for growth differences between young firms (due to register problems in the province of Friesland and the city of Groningen, firms in these regions are excluded from the analysis).

4.5 Empirical results

Table 4.3 summarizes our model results. Because our focus is on the final 'unconditional growth' estimation, we first discuss our finding of the Heckman models. In these models, firms with one employee are not taken into account, and all variables are log-transformed. The last part of this section summarizes the findings of the preceding survival models. Many robustness analyses using different model specifications were carried out, but we do not report results from the individual analysis.

4.5.1 Unconditional growth

Controlled for the firm specific characteristics of age, size and sector, the most important issue in our research is the impact of the variables representing external local knowledge resources: 'knowledge workers', 'innovation' and 'R&D'. In models (2), (4) and (7) in Table 4.3 we consider firms that survived until 2006.

The positive and significant coefficients of 'innovation' and 'R&D' indicates that firms experience higher growth rates when located in a city (municipality) with a high intensity of successful innovative firms or with a high intensity in research and development activities. This implies that localized knowledge externalities in firm growth are related to the density of technological inputs on the one hand, and to proximity to the density of successful, innovative firms and institutions on the other. The positive relation between knowledge intensity and firm growth cannot be extended to the factor 'knowledge workers'. Proximity to economic activities that can be characterized by a high degree of education, ICT-use and communicative and creative skills has no effect on firm growth (model (2)).

The comparison between the general model (2) and the separate models for manufacturing (4) and business services (7) brings differences between the two types of economic activities to the fore. As we concluded that the 'knowledge workers' intensity has no significant impact on firm growth, this is apparently only true for manufacturing firms. For business services we do find a positive relationship of firm growth with the intensity of the knowledge workers dimension. Firms in business services profit from being located nearby 'softer, less technological' knowledge resources. As mentioned, this factor is more strongly related to service activities and in spatial terms to cities and agglomerations (Raspe and Van Oort, 2006).

We find indications for spatially bounded R&D-externalities, but this is mainly the case for business services and not for manufacturing firms. On first sight this is not what we expected, because the literature indicates that especially manufacturing firms profit from proximity to technological knowledge sources because these activities are close to their own activities and knowledge base. One explanation might be that physical proximity and localized externalities matter less for manufacturing than do knowledge externalities networks over longer distances (Ponds et al. 2007). Firm growth in business services firms on the other hand is enhanced by proximity to technological knowledge resources. It seems that these firms profit from a high intensity of R&D close by. The finding that service firms grow faster in technological-dense environments might be due to service-related multipliers of manufacturing firms. A robust finding is the positive impact of the knowledge factor 'innovation' for both the growth of manufacturing and business services firms. This can be interpreted as the grasping of entrepreneurial opportunities by innovation, and thus subscribes the literature on entrepreneurship and (regional) economic growth in which it is hypothesized that a vivid entrepreneurial environment accelerates growth (Audretsch and Dohse 2007).

We also took sector specific characteristics into account. To fulfill Europe's ambition to become the world's most competitive and dynamic knowledge based economy, the Dutch Ministry of Economic Affairs defined so-called key sectors (EZ 2005): high-tech, chemistry, creative industries, financial services and ICT. Surprisingly, for our research period 2001-2006, these industry specializations were not all related to additional firm employment growth. Both the high-tech and chemistry sectors had a positive growth effect, while the business services related ICT, creative industries and financial services all had a negative impact. Generally, these economic activities were hit by negative economic circumstances since the burst of the 'New Economy bubble' in the first part of our growth period. We can in fact conclude that although the sectors are defined by their supposed growth potential by the national government, growth in the firms in these sectors is lagging behind.

With respect to the firm-level variables, the impact of *AGE* and *SIZE* is generally assumed to have a negative impact on firm growth, indicating that firm growth tends to decline as the firm evolves over its life cycle (Audretsch and Dohse 2007). Evans (1987) argues that this theory generally implies that growth decreases with age. We indeed find this effect in our manufacturing model (4), but not for business services (7). This latter result fits with conclusions by Audretsch et al. (2004), who find that especially for small services activities there is no negative age-growth relationship. With respect to *SIZE* we expect that growth declines with firm size, but as firms grow very large (hence the introduction of the size-squared term), it is expected that growth decreases more slowly. Our *SIZE* coefficient is not significant, while the $SIZE^2$ is positive and significant (in all models (2), (4) and (7)). This is clearly related to the characteristics of the Dutch economy, with many small firms. Consequently, the size effect only comes to the fore in the size-squared term (see table 4.2). We therefore conclude that this fits our hypothesis that size (measured by $SIZE^2$) has a negative impact on firm-level growth.

4.5.2 Survival

To determine the unconditional growth of firms we controlled for panel attrition: the non-survival of firms in the research period. The probit models were initially necessary to correct for potential selection bias caused by sample selection of non-survivors, but these survival models can also be interpreted on their own merits, questioning whether firm internal and knowledge related external factors influence firm survival.

Concerning our external knowledge resources we can conclude that 'innovation' is the main factor increasing a firm's chance of survival. Being located in a region that is successful in innovation positively influences firm survival, in the general model (1) as well as in the models for manufacturing (3) and business services (6). As we concluded earlier, firm growth (after survival) is also positively affected by proximity to innovation as an external knowledge resource. We can thus conclude that innovation is the most significant knowledge factor. The other knowledge factors 'knowledge workers' and 'R&D' appear to be insignificant for survival.

Our analyses confirm that the age of firms is negatively related to exit rates, especially when (very) small firms are included in the analysis (Evans 1987). The probability of failure decreases with firm age. We also observe that the relationship between initial size and survival is significantly negative, implying that smaller firms have a higher probability to survive than larger ones. This result is not consistent with studies conducted in other countries. The quadratic term of size is positive and significant for survival, implying that the negative effect of size on growth diminishes for larger size classes. As we know that especially the Dutch medium size firms (10 till 100 employees) had difficulties in surviving during the research period, this might be one of the reasons for these results.

4.5.3 Interaction-effects

In our models we also took interaction effects into account within the growth models; we tested for the additional effect that certain industries might profit from a location in a knowledge intensive context, illustrated in columns (5) and (8) in table 4.3. Interaction effects are the product of two direct effects that are simultaneously modeled in the same model. In our models this concerns the product of the industry dummy and the spatial knowledge factors. Note that in models with interaction effects the direct effects cannot be interpreted independently and should always be considered together with the interaction variables. Again, we focus on the sectors defined by the Dutch Ministry of Economic Affairs defined as so-called key sectors: high-tech industries, chemistry, creative industries, financial services and ICT. Most remarkable is that for our research period 2001-2006 these industry specializations are not all related to additional, firm-level employment growth.

Model (5) shows that neither high-tech nor chemistry firms profit to any great degree from a location within a region with higher intensity of 'knowledge workers', 'innovation' or 'R&D'. Firms in these sectors, with an expected sensitivity for external technological knowledge in particular, R&D and potential advantages of a location in the proximity of this kind of knowledge, experience no additional locational effect. Firms in ICT and creative industries also do not face additional advantages of a location with a high knowledge intensity. As in the model (7) we found positive impacts of all three knowledge factors, none of them seem to additionally foster ICT firms and firms in creative industries. In our research period, these economic activities encountered negative economic circumstances since the burst of the 'new economy bubble'. Although defined as having a growth potential by the national government, growth in these firms is not exceptionally higher than average. We do find such an effect for financial service firms, though. These firms profit from a location with a higher intensity of 'knowledge workers'. Proximity to other firms characterized by

Table 4.3 Firm survival and growth 2001-2006 (std. dev. in parentheses)

	Manuf.& Bus.Services			Manufacturing		Business services		
	(1)Probit *SURVIVAL*	(2)Heckman *GROWTH*	(3)Probit *SURVIVAL*	(4)Heckman *GROWTH*	(5)Heckman *GROWTH*	(6)Probit *SURVIVAL*	(7)Heckman *GROWTH*	(8)Heckman *GROWTH*
Constant	-9.234***	0.078	-10.756***	0.839**	0.832**	-8.852***	-0.027	-0.013
	(0.415)	(0.155)	(0.894)	(0.330)	(0.327)	(0.470)	(0.183)	(0.183)
AGE	1.420***	-0.024	1.608***	-0.115***	-0.114***	1.371***	-0.012	-0.013
	(0.010)	(0.020)	(0.024)	(0.042)	(0.041)	(0.012)	(0.023)	(0.023)
SIZE	-0.440***	0.012	-0.463***	0.010	0.009	-0.417***	0.007	0.009
	(0.034)	(0.009)	(0.073)	(0.013)	(0.013)	(0.051)	(0.012)	(0.012)
SIZE^2	0.054***	-0.005***	0.057***	-0.005***	-0.005***	0.051***	-0.004**	-0.005**
	(0.006)	(0.001)	(0.011)	(0.002)	(0.002)	(0.007)	(0.002)	(0.002)
HIGHTECH	0.054	0.067***	0.098	0.048***	0.039**	-	-	-
	(0.050)	(0.013)	(0.068)	(0.013)	(0.017)			
CHEMISTRY	0.125*	0.071***	0.213***	0.060***	0.041**	-	-	-
	(0.072)	(0.017)	(0.081)	(0.015)	(0.019)			
ICT	0.348***	-0.050***	-	-	-	0.318***	-0.038***	-0.037***
	(0.034)	(0.011)				(0.035)	(0.013)	(0.019)
CREATIVE IND.	-0.050	-0.066***	-	-	-	-0.073**	-0.059***	-0.064***
	(0.032)	(0.009)				(0.031)	(0.010)	(0.013)
FIN.SERVICES	-0.242***	-0.086***	-	-	-	-0.260***	-0.078***	-0.112***
	(0.027)	(0.008)				(0.028)	(0.009)	(0.012)
'KW'	0.014	-0.001	-0.034*	-0.014***	-0.018***	0.015	0.007**	0.001
	(0.009)	(0.002)	(0.020)	(0.004)	(0.004)	(0.010)	(0.003)	(0.004)
'INN'	0.066***	0.021***	0.052**	0.011***	0.008*	0.068***	0.026***	0.024***
	(0.011)	(0.003)	(0.023)	(0.004)	(0.005)	(0.012)	(0.004)	(0.005)
'R&D'	-0.009	0.006**	-0.014	0.001	0.003	-0.003	0.009***	0.011***
	(0.009)	(0.002)	(0.019)	(0.004)	(0.004)	(0.010)	(0.003)	(0.004)
LAMBDA	-	-0.029	-	-0.129*	-0.127*	-	-0.016	-0.019
		(0.040)		(0.071)	(0.070)		(0.049)	(0.049)
INSTR[1]	-0.182**	-	-0.223	-	-	-0.169*	-	-
	(0.085)		(0.184)			(0.097)		
HIGHT'KW'*	-	-	-	-	0.014	-	-	-
					(0.013)			
HIGHT'INN'*	-	-	-	-	0.020	-	-	-
					(0.015)			

	Manuf.& Bus.Services			Manufacturing		Business services		
	(1)Probit *SURVIVAL*	(2)Heckman *GROWTH*	(3)Probit *SURVIVAL*	(4)Heckman *GROWTH*	(5)Heckman *GROWTH*	(6)Probit *SURVIVAL*	(7)Heckman *GROWTH*	(8)Heckman *GROWTH*
HIGHT'R&D'*	-	-	-	-	-0.014 (0.012)	-	-	-
CHEMIS'KW'*	-	-	-	-	0.024 (0.015)	-	-	-
CHEMIS'INN'*	-	-	-	-	0.023 (0.018)	-	-	-
CHEMIS'R&D'*	-	-	-	-	0.004 (0.014)	-	-	-
ICT'KW'*	-	-	-	-	-	-	-	-0.003 (0.013)
ICT'INN'*	-	-	-	-	-	-	-	0.007 (0.015)
ICT'R&D'*	-	-	-	-	-	-	-	0.003 (0.012)
CREA'KW'*	-	-	-	-	-	-	-	0.004 (0.010)
CREA'INN'*	-	-	-	-	-	-	-	0.004 (0.012)
CREA'R&D'*	-	-	-	-	-	-	-	-0.009 (0.010)
FIN.S'KW'*	-	-	-	-	-	-	-	0.040*** (0.009)
FIN.S'INN'*	-	-	-	-	-	-	-	0.005 (0.010)
FIN.S'R&D'*	-	-	-	-	-	-	-	-0.006 (0.009)
Adj. R2	-	0.005	-	0.007	0.007	-	0.004	0.005
N	86,916	62,030	22,955	18,159	18,159	63,961	43,871	43,871

*** significant at 0.01. ** significant at 0.05. * significant at 0.10

a highly educated, communicative and creative workforce using ICT has advantages for financial services firms.

To sum up, we find that firm level employment growth is influenced by locational knowledge intensity characteristics as well as characteristics specific to the firm and the industry. In particular, the empirical evidence suggests that being located in an innovative environment is more conducive to firm growth than being located in a region that is less endowed with knowledge resources. For spatial intensity of 'knowledge workers' and 'R&D' this is confirmed in sectoral models as well.

We carried out several robustness analyses. First we tested for the impact of agglomeration in general, by introducing population and job density in the models. We also tested whether regime-modeling of the Dutch Randstad region is important (Van Oort 2004). Although positively related to the unconditional growth equation, these agglomeration indicators appeared to be especially highly correlated with our factors 'knowledge workers' and 'innovation', and for that reason they were not included in the final models simultaneously with the knowledge factors. Second, we tested for a possible effect of the Dutch border regions, as in Raspe and Van Oort (2006). Because this effect turned out not to be significant, we left this indicator out of the models. Thirdly, we checked for panel bias for the first year of the growth period, 2001, by estimating the same models for survival and growth for the period 2002-2006. We concluded that the levels of significance and direction of the parameters remain largely intact. The probit model does not change, while in the 'all firm' and 'business services' models AGE is negatively related to growth, taking over the negative impact of size-squared.

4.6 Conclusions

In this paper we contribute to the discussion on linking firm external knowledge environments to individual firm growth potentials. We question whether knowledge characteristics of a firm's location impact on its growth. We defined the spatial knowledge environment of firms on a low spatial scale: that of Dutch municipalities – the level of cities – as a natural context to understand the mechanics of economic growth in relation to the compact geographical nature of communication and knowledge flows. When knowledge is not easily exchanged over distance, firms tend to locate in proximity to others in order to capitalize on the knowledge stock in neighboring firms and institutions. For this context of knowledge stock we define the latent concept of 'knowledge economy' using three dimensions: 'research and development', 'innovation', and 'knowledge workers' – the latter including the use of ICT, educational level of the workforce, communicative and creative skills. Based on the knowledge economy literature, we not only focus on R&D or technological externalities, but we also value complementary indicators, like the successful introduction of new products and services to the market ('innovation') and indicators of skills of employees ('knowledge workers').

Simultaneously controlling for the firm's age, size (which in general have the expected effects in the models) and industry membership, we indeed find indications that firms experience higher growth rates when located in a region with a higher intensity of successful innovative firms or with a high intensity of research and development activities. Splitting the analysis into separate models for manufacturing and business services gives the insight that whereas employing 'knowledge workers' has no significant impact on firm growth in general, for business services it does foster growth. As this factor is spatially related to cities and agglomerations rather that rural and peripheral regions, this strengthens the hypothesis that the growth of business service firms is enhanced by urban knowledge contexts.

On the contrary, as we found a positive R&D-effect in the general model, this does not apply specifically to manufacturing firms. On first sight this is not as expected, since the literature indicates that manufacturing firms in particular profit from proximity to technological knowledge source because these activities are close to their own activities and knowledge base. An explanation might be that physical proximity and localized externalities matter less for manufacturing than knowledge externalities networks across longer distances do. The finding that service firms grow faster in technological-intense environments might be due to service-related multipliers of manufacturing firms. A robust finding is the positive impact of the knowledge source 'innovation' for the growth of manufacturing as well as business services firms. As we further investigate industry specific fixed effects related to policy defined key sectors, our research indicates that as such these industry specializations are not, by definition, related to additional firm employment growth. Although defined for their suggested growth potential by the national government, growth in these firms is not exceptionally higher than average. We only found this effect for financial services, related to a location with a higher intensity of 'knowledge workers'.

In our paper we modeled unconditional firm growth (controlled for the non-survival of firms in the research period). We found that for both firm survival and firm growth following survival, locational characteristics as well as firm-specific characteristics play a role. While the literature on knowledge spillovers as well as policymakers tend to focus on technological (R&D-related) spillovers, we suggest broadening this perspective: a focus limited to manufacturing and R&D seems to be too narrow to grasp the whole knowledge related growth potential. Regional economic policies aiming at innovation valorization, entrepreneurship and enhancing educational, ICT, communicative and creative skills, can be particularly fruitful. We found that spillover advantages are not related to specific industries, but on the contrary are firm specific. Regional policymakers should therefore take particular care to tailor their efforts to suit the needs of individual firms.

Appendix 4.1 Descriptive statistics of the growth models

Table 4.4 Descriptives

		Minimum	Maximum	Mean	St.Deviation
All firms (n= 62,030)	*GROWTH*	-5.28	4.94	-0.12	0.63
	AGE	6.00	8.00	7.82	0.52
	SIZE	0.92	9.16	2.27	1.14
	SIZE²	0.84	83.91	6.46	7.11
	HIGHTECH	0.00	1.00	0.04	0.20
	CHEMISTRY	0.00	1.00	0.02	0.15
	ICT	0.00	1.00	0.06	0.24
	CREATIVE IND.	0.00	1.00	0.09	0.29
	FIN.SERVICES	0.00	1.00	0.11	0.31
	'KW'	-2.23	3.89	0.74	1.08
	'INN'	-2.11	1.99	0.41	0.94
	'R&D'	-1.90	3.95	0.13	1.11
Manufacturing (n= 18,159)	*GROWTH*	-4.81	3.32	-0.09	0.53
	AGE	6.00	8.00	7.91	0.38
	SIZE	0.92	9.16	2.60	1.24
	SIZE²	0.84	83.91	8.28	8.23
	HIGHTECH	0.00	1.00	0.11	0.31
	CHEMISTRY	0.00	1.00	0.08	0.27
	'KW'	-2.23	3.89	0.33	1.02
	'INN'	-2.11	1.99	0.25	0.92
	'R&D'	-1.90	3.95	0.34	1.07
Business Services (n= 43,871)	*GROWTH*	-5.28	4.94	-0.14	0.67
	AGE	6.00	8.00	7.79	0.57
	SIZE	0.92	8.25	2.14	1.07
	SIZE²	0.84	68.07	5.71	6.44
	ICT	0.00	1.00	0.08	0.27
	CREATIVE IND.	0.00	1.00	0.13	0.34
	FIN.SERVICES	0.00	1.00	0.15	0.36
	'KW'	-2.23	3.89	0.91	1.06
	'INN'	-2.11	1.99	0.47	0.94
	'R&D'	-1.90	3.95	0.05	1.11

Dependent variables SIZE, $SIZE^2$, are in logarithms. HIGHTECH, CHEMISTRY, ICT, CREATIVE INDUSTRIES and FINANCIAL SERVICES are dummies, KW = Knowledge workers, INN = Innovation, R&D = Research & Development are standardized outcomes of the factor analyses (see section 4.3).

Appendix 4.2 Sectors by NACE codes

Table 4.5 Sectors by NACE codes

HIGHTECH	2442, 2921, 2924, 2943, 3001, 3002, 3120, 3130, 3161, 3162, 3210, 3220, 3230, 3320, 3340, 33101, 33102, 3530, 3630, 7250, 7320, 73101, 73102, 73103, 73104
CHEMISTRY	1110, 1120, 23201, 23202, 2330, 2411, 2412, 2413, 24141, 24142, 2415, 2416, 2417, 2420, 2430, 2441, 2442, 2451, 2452, 2461, 2462, 2463, 2464, 2465, 2466, 2470, 2511, 2512, 2513, 2521, 2522, 2523, 2524, 6322
ICT	3001, 3002, 3130, 3210, 3220, 3230, 3320, 6420, 7210, 7221, 7222, 7230, 7240, 7250, 7260
CREATIVE IND.	2211, 2212, 2213, 2214, 2215, 74201, 74202, 74401, 74402, 74811, 74875
FIN.SERVICES	6322, 6511, 6603, 6711, 6712, 65121, 65122, 65123, 65124, 65221, 65222, 65223, 65224, 65231, 65232, 65233, 65234, 66011, 66012, 66013, 66021, 66022, 66023, 66024, 67131, 67132, 67133, 67201, 67202, 67203, 67204, 67205

5 Firm heterogeneity, productivity and spatially bounded knowledge externalities[24]

Abstract

Within regional economic analysis, the question of whether contextual effects (externalities) or firm-level composition effects foster regional advantage is a current one. It is increasingly stressed that there is a strong need to allow for firm heterogeneity within spatial-economic studies. To minimize confounding, it is imperative to recognize that there is a 'level of the firm' and that there is a 'level of regions'. In this paper, we argue that conceptually the disentangling of 'context versus composition' aspects of regional growth is a multilevel issue. By applying multilevel models, we show (1) the importance of taking firm-specific characteristics, simultaneously with region-specific characteristics, into account, since we find that a large part of what 'traditionally' is assigned to the impact of the region should be assigned to firm-specific characteristics, and (2) that existing single-level methodologies can be problematic, since they are vulnerable to the charge of estimating significance levels that are too liberally assigned and promoting exaggerations. This is illustrated empirically by showing that single-level approaches would lead to the conclusion that innovation spillovers are highly significant, while multilevel analyses shows less liberally assigned significance levels. We conclude that multilevel effect models better fit research questions that combine firm and spatial characteristics simultaneously, especially since they also allow the estimation of whether certain firm-specific characteristics turn out to be differently linked to their regional contexts.

5.1 Introduction

The geographical aspect of economic activities has long been of interest to many economists, geographers, planners, and regional scientists. Over the years, these disciplines have provided us with a large body of literature that provides insight into why some regions perform better than others and how interactions between increasing returns to scale, scope and expertise of firms and geographic location lead to a particular distribution of economic activities. Showing a positive correlation between geographical clustering, agglomeration and regional productivity, economic growth or innovation, it often is stressed that 'the region matters'.

However, several authors recently have stressed the poor conceptualization or even total neglect of 'the firm' in economic geography (Taylor and Asheim 2001, Maskell 2001, Boggs and Rantisi 2003). One also argues that, despite the empirical evidence about the linkages between regionally bounded advantages (externalities) and growth focus on regional and local entities, the relationship should actually and most profoundly hold at the micro or firm level. According to Audretsch and Dohse (2007), in fact very little is known about the locational impact on firm performance because

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of limitations in both the conceptualization of the linkage between regions and firms as well as data availability.[25]

For two reasons, it is important to descend to the level of the firm. First, in line with Beugelsdijk (2007), one can say that if one takes the argument about the role of the region seriously, then one needs to test it at the proper level of analysis: the firm. The firm can be considered the relevant 'phenotype', that is, the unit to which economic selection applies its grip and in which adaptation is embodied (Nooteboom 1999). When arguments that 'the region matters' are deduced from a macro-level phenomenon of, for example, regional clusters, but is used as micro-level 'evidence', this makes one's work vulnerable to the charge of the *ecological fallacy*. A correlation found at the regional level does not necessarily mean the same as a correlation at the individual level. In the literature, this is also known as the 'Robinson effect' after Robinson (1950), which is the interpretation of aggregated data at the individual level.

Second, in line with the first argument, there is an urge to 'control' for firm-specific characteristics, since their unequal distribution over space can be a major explanation for why regional economic differences occur. For example, firm size, age and industry membership can be related to firm productivity, and when larger and older firm, or firms in certain industries, cluster in specific regions, this results in higher regional performance rates (composition effects). Not controlling for this firm heterogeneity has the danger to wrongfully assign an impact to 'regions'. Regional analyses therefore potentially overestimate the importance of regional externalities, as firms that started in or moved into the region might show higher-than-average firm performance (Baldwin and Okubo 2006).

In this paper, we try to contribute to a better understanding of the relation between 'the firm' and 'the region'. According to Dicken en Malberg (2001), in addition to a stronger focus on 'the firm' as central actor, this also means the development of methods for analyzing interactions and relationships, particularly those involving the exchange of information and knowledge - across economic systems - in order to assess the extent to which such interactions and exchanges are carried out within bounded territories. We show the importance of taking firm-specific characteristics (i.e., firm heterogeneity) into account while testing for the effects of regional characteristics (spatial externalities) in explaining productivity of firms. This will be illustrated empirically by showing that 'more firm conceptualizations in geography' should not be reduced to microanalysis in which regional variables are 'simply' linked to the micro actors. We argue that existing single-level methodologies can be problematic and that alternative methodologies (like multilevel analysis) can provide a comprehensive framework to empirically address the key contextual considerations of the firm embedded in its regional contexts. Applying multilevel models, we find that indeed, a large part of what 'traditionally' is assigned to the impact of the region should be assigned to firm-specific characteristics.

The paper is further organized as follows. The next section elaborates on our plea for a multilevel approach and suggests multilevel analysis as a representation of this approach. Section 5.3 describes

25 Empirical geographical analyses that include firm-level data are relatively scarce. The lack of these kinds of data is one of the reasons why (regional) studies fail to include firm-specific characteristics. In this study, we use detailed data stemming from a firm survey in the Netherlands.

the indicators that will be taken into account theoretically (both firm-specific and region-specific). Section 5.4 shows our empirical approach, followed by the results of the multilevel modeling in section 5.5. We conclude in section 5.6.

5.2 A plea for a multilevel approach

Within regional economic analysis, the question of whether contextual effects or firm-level composition affects foster regional advantage is still an actual one (Saxenian 1994, Van Oort 2004). In line with the ecological fallacy arguments, several authors have recently claimed that there is a strong need to allow for firm heterogeneity within spatial-economic studies (Baldwin and Okubo 2006, Koo and Lall 2007, Mariani 2004). It is necessary to minimize confounding, meaning that it is imperative to recognize that there is a 'level of the firm' and that there is a 'level of regions'. Both firms and regions have their own specific characteristics (heterogeneity), which simultaneously have to be taken into account. Conceptually, the disentangling of 'context versus composition' aspects of regional growth is a multilevel issue. If regions vary in advantages (after allowing for firm-specific compositional characteristics), it is necessary to ascertain whether the variation between regions is similar for firms or whether the variation differs for firms. Having unpacked the regional variation, one needs to explore the interconnections between firm performance and these contextual factors.

As we start from the assumption that it is 'generally acknowledged that contextual variables should be related to firm performances,' the question is how best to treat the contextual variables. Often this is done by disaggregating the contextual variables and linking the value of a variable at the regional (higher) level to all units at the lower level to which they belong. This disaggregation exaggerates the regional values because information from fewer regional units is treated as if it were independent data for the many units at the micro level. This *atomistic fallacy* (conceptually the reciprocal of the ecological fallacy) inhabits the danger of drawing false conclusions, as there is no necessary correspondence between individual-level and group-level relationships. This might lead to errors in sample size treatment, providing over-optimistic estimates of significance and correlated errors of firms belonging to the same context, which violates one of the basic assumptions of multiple regression analysis (Hox 2002).

Multilevel or random effect modeling provides a conceptual methodological framework that simultaneously takes firm and regional levels and their characteristics into account without facing the atomistic fallacy problem. The general idea of this modeling, which takes different levels of analysis into account, is that individuals and social groups are conceptualized as a hierarchically nested system with individuals and groups defined at separate levels (Hox 2002; Goldstein 2003). Individuals in the same social context show similar progressive behavior. Contrary to standard multivariate models, multilevel models control for the assumption of independence of observations in grouped data. The most researched multilevel cases are within educational studies: students learn by individual and class influences. Earlier examples of spatial or area-related studies hierarchically model individual health, social contacts and voting behavior embedded in spatial contexts. In these cases, the lowest (micro) level is an individual, and higher levels consist of neighborhoods, regions or countries. We want to test whether firm productivity is hierarchically nested in and influenced by its (spatial) context. Since firms within a geographical context are close in space, we expect that they are more similar in performance than firms in other regions. This co-variation between firm's performances sharing the same regional externalities can be expressed by the *intra-class* correlation (Hox 2002, see appendix 5.1). With intra-class correlation, the between-regions variance contributes to individual firm growth as well as to the between-firm growth variance.

5.3 Firm-specific characteristics and spatially bounded knowledge externalities

One of the leading indicators in the debate of locational impact on firm performance is 'productivity' (Ciccone and Hall 1996, Moomaw 1981, Lucas 1993, Kim 1997). In particular, studies on industrial dynamics and entrepreneurship have a long tradition in theorizing why firm productivity varies systematically across firms and which 'internal factors' are related to this phenomenon (Sutton 1997, Caves 1998). We do not give a full overview of this debate, but rather distillate the most relevant elements that are related to productivity.[26]

5.3.1 Firm-specific characteristics

The literature on industrial organization suggests the importance of firm size, age, and industry. It is often argued that firm size largely determines a firm's resource base, competencies and scale advantages. For instance, due to 'internal economies of scale' causing a reduction in per-unit costs over the number of units produced, efficiency advantages emerge from larger firm sizes (Jovanovic 1982; Carroll and Hannan 2000). Small firms, due to their limited initial size, have to overcome these disadvantages, unlike larger firms.

A considerable number of studies bring to the fore that in addition to size, the ossification of routines and learning processes can also be important (Sutton 1997). It appears to be especially important to take a firm's age into account (Jovanovic 1982). Firms learn from their own experience. Young firms can grow and become more efficient (i.e., reduce their costs), while the unsuccessful ones remain small or may be forced to exit the industry. Here, age is the representative of the selection processes due to learning over time. This leads to the assumption that older firms function more efficiently, indicating that firms can learn from their own experience and successful firms grow and become more efficient (i.e., reduce their costs), while the unsuccessful ones face lower productivity levels. On the other hand, it can be hypothesized that firm productivity tends to decline as the firm evolves over its life cycle. Older firms can suffer from path dependency and see themselves as confronted with 'lock in', meaning that older firms have lower productivity rates (Brouwer 2005). This lock-in can be described as the competency trap; becoming quite good at doing any one thing reduces an organization's capacity to absorb new ideas and to do other things (Levitt and March 1996). It often turns out to be difficult to unlearn habits and routines that have been successful in the past but that have become redundant over time (Boschma 2004). Evans (1987) suggests assuming a non-linear relationship between performance and age. Age is assumed to positively affect productivity. Although this does not hold for the 'oldest' firms, which potentially suffer from 'lock in' and inefficient routines.

26 See Audretsch and Dohse (2007) for an overview of relevant indicators. We realize that these indicators are not fitted in one conceptual framework. See Raspe (2009) The regional knowledge economy; a multilevel perspective on firm performance and localized knowledge externalities, chapter 1 and 2 for such a framework.

In addition to size and age, the type of economic activity (*industries*) is indicated as important for firm performance. Industry-related effects capture various technology and knowledge dimensions such as technological opportunity, appropriability regimes, or the emergence of dominant designs along the technology life cycle (Teece 1986, Breschi et al. 2000). This results in productivity differences stemming from industry membership.

In particular, the management science literature has recently stressed the importance of firm 'competences and resource', especially concerning a firm's *internal knowledge base* as enhancing productivity (Foss 1998, Grant 1996). Often mentioned is a firm's *absorptive capacity*, both in terms of understanding where the potential sources of knowledge reside and the ability to absorb and deploy external knowledge (Cohen and Levinthal 1990). The ability to identify, assimilate and apply for commercial purposes know-how generated outside a firm's own organization, is considered to be one of the most relevant business characteristics in determining the productivity and innovativeness of firms (Nieto and Quevebo 2005). Internal competencies here pre-condition the ability to identify, assimilate and apply know-how generated outside one's own organization.

Consistent with the absorptive capacity arguments, there is particular interest in the effect of transfer mechanisms like *face-to-face* interaction. Interaction between firms is considered to be fostered by face-to-face interactions, especially where it deals with tacit knowledge (Storper and Venables 2004), McCann and Simonen 2005). The competence-based approach emphasizes the importance for performance of largely tacit and socially produced and reproduced knowledge (Foss 1998). In particular, the information used by innovators has a tacit component; there is information that is difficult to set down in blueprints or to codify completely, and hence it is difficult to communicate at a distance. Face-to-face interaction can enhance productivity, since it unlocks (more and better) knowledge sources (Glaeser 1999).

At least the same amount attention is being paid to the use of *information- and communication technologies* (*ICT*). In particular, Drennan (2002) and Black and Lynch (2001) analyze the potentials of firms related to an increased accessibility of information through the adoption of information- and communication technologies (ICT). Especially for productivity, recent studies suggest that ICT as a general-purpose technology enhances productivity by making working processes more efficient (Becchetti et al. 2003; Van Ark and Piatkowski 2004).

5.3.2 Spatially bounded externalities

Next to firm-level approaches, economic geographers and regional scientists especially stress regional causes of productivity advantages. Firms cluster and profit from densities to economize on the transport of goods, people, and ideas (Ciccone and Hall 1996, Moomaw 1981, Lucas 1993, Kim 1997). These three motives for economic agglomeration are also known as availability of intermediate/final goods, labor market pooling, and knowledge spillovers, respectively (Combes and Duranton 2006). In particular, knowledge spillovers (or externalities) form a mechanism in firm-external economies and are considered a key element of productivity and growth (Henderson 2007, Koo 2005). Cities are considered to be centers of innovation and technological progress i.e., centers of the production of ideas and knowledge (Storper and Venables 2004). The notion frequently adopted to explain these facts is that spatial proximity improves flows of information that innovators use in being innovative.

These regional externalities are often elaborated on in so-called agglomeration economies. These can be divided into localization and urbanization economies and Jacobs's externalities (Frenken et al. 2007). Localization economies are externalities available to all local firms within the same sector. They usually take the form of what are called Marshallian (technical) externalities, whereby the productivity of labor in a given sector in a given city is assumed to increase with total employment in that sector. Urbanization economies are external economies available to all local firms, irrespective of sector and arising from urban size and density. These reflect external economies that are passed to enterprises as a result of savings from the large-scale operation of an agglomeration or city as a whole and that thus are independent of industry structure. Relatively more populous localities are also more likely to house universities, industry research laboratories, trade associations and other knowledge-generating organizations. Jacobs' externalities are external economies available to all local firms from a variety of sectors. The diverse industry mix in an urbanized locality also improves the opportunities to interact, copy, modify, and recombine ideas, practices and technologies across industries.

These types of economies (localization, urbanization and Jacobs) define externalities only implicitly stemming from knowledge; they do not directly measure technological and production-oriented spillover potentials or human capital-related elements. These latter have especially been indicated in studies by Feldman and Audretsch (1999), Glaeser et al. (1992) and Storper and Venables (2004). Concerning technological spillovers, most attention has traditionally been paid to research and development (R&D) in this context (Black 2004). In line with the work of Arrow (1962) and Griliches (1979), a large body of empirical work has found a strong and positive relationship between R&D on one hand and innovative outputs on the other hand over the years (Audretsch 2003). This is extended by, for example, Jaffe (1989) and Mansfield (1995), who, as pioneers in the field of technological spillovers, state that the productivity of a firm's own research may be affected by the size of the pool or pools it can draw upon. Research and development external to a firm can function as input for other firms.

The literature also stresses that, ultimately, *innovation* is generally regarded as an important driver of economic and employment growth. As innovation can be defined as the successful introduction of new products (or services) to the market, this is not the same as R&D. Not all trial and error processes lead to new products. And not all new products have a long tradition in R&D activities. Besides 'R&D'-related indicators, therefore, successful renewal ('innovation') is also addressed. As innovation is an outcome of research findings (in the case of manufacturing firms) and is therefore shown in new products, it also contains new services (mainly in the case of business services firms). Innovation can be related to own investments as well as to external elements. For a part, this also can be the imitation of products and services competitors bring to the market.

Another external knowledge source is human capital. Lucas (1993) and Mathur (1999) argue that education is a particularly crucial feature of the knowledge economy. A well-educated workforce has ample opportunities to absorb and use information. Besides the direct effect of the level of education on economic output, human capital also has a spillover potential. Human capital externalities may arise if the presence of educated workers makes other workers more productive. If externalities exist, we should see that plants located in cities with high levels of human capital can produce a greater output with the same inputs than otherwise similar plants located in cities with low levels of human capital (Moretti 2004). Empirical studies of Moretti (2004) and Wheeler

(2007) indeed find such effects. Increases in the stock of local human capital lead to increases in the amount of knowledge that is generated and exchanged within a local market, and these increases enhance productivity.

To finalize the literature review, some more conventional variables should also be taken into account to control for more general spatial advantages (see Frenken et al. 2007, Raspe and Van Oort 2006, Audretsch et al. 2006). These are: (1) regional growth, implying increasing market size, hence creating general opportunities for business, (2) spatial investment levels, an indication of physical renewals in the production environment, (3) industry wages, indicating the differential between high-skilled labor and standardized mass-production by low-skilled labor, (4) newly built business premises, since they attract economic activity that previously was not present in that location, and migrated firms often turn out to perform better when located at their new location, (5) accessibility, and (6) presence of a university.

5.4 Empirical approach: variables and modeling

We model firm productivity, simultaneously taking both firm-specific and region-specific independent variables into account. Therefore we use multilevel models (see appendix 5.1 for some elaboration on these kinds of models). Formula 5.1 summarizes our full model:

$$\begin{aligned}\mathrm{PROD}_{ij} &= \beta_{0j} = \beta_1 SIZE_{ij} + \beta_2 AGE_{ij} + \beta_3 AGE\_SQ_{ij} + \beta_4 AI_{ij} + \beta_5 CI_{ij} + \beta_6 KI_{ij} + \beta_7 KI.OC_{ij} + \\ &\beta_8 F2F_{ij} + \beta_9 ICT_{ij} + \beta_{10} SPEC.AI_j + \beta_{11} SPEC.CI_j + \beta_{12} SPEC.KI_j + \beta_{13} DENSITY_j + \\ &\beta_{14} GINI_j + \beta_{15} R\&D_j + \beta_{16} INN_j + \beta_{17} EDU_j + \beta_{18} RED.GROWTH_j + \beta_{19} INVEST_j + \\ &\beta_{20} WAGE_j + \beta_{21} BUS.SITES_j + \beta_{22} ACCESAB_j + \beta_{23} UNIV_j + e_{ij} \qquad (5.1)\end{aligned}$$

where

$$\beta_{0j} = \beta_0 + \mu_{0j} \qquad (5.2)$$

(i refers to firms and j to regions).

For the firm-level data, our paper draws on a survey with data concerning 2,009 firms in manufacturing and business services. The survey was conducted in 2005 (see appendix 5.2).

At the firm level, our performance indicator is the level of labor productivity ($PROD_{ij}$), measured as the added value of a firm per employee. The firm's added value is determined as the yearly turnover minus purchases (all intermediate goods and service needed in the production process of the firm). The added value includes the firm's taxes, subsidy, wages, and profits. Labor productivity is distilled by dividing the added value at the firm level by the number of employees (defined as the number of employees with 12 hours of work or more per week corresponding to the definition of Statistics Netherlands).

As mentioned above, hypotheses exist regarding the influence of size ($SIZE_{ij}$) and age (AGE_{ij}) on firm productivity. We take firm size into account by the firm's turnover. Our hypothesis is that firm size is positively related to labor productivity; larger firms are better organized and potentially profit from divisions of labor within the firm. Age is measured by the number of years since the firm has entered business (year of foundation of the establishment). Our hypothesis is that age is positively related to a firm's productivity, unless firms suffer from lock-in (represented by including an age-squared variable AGE_SQ_{ij} simultaneously with the non-quadratic age term).

A firm's absorptive capacity depends to a large extent on its existing (prior) stock of knowledge, much of which is embedded in its products, processes and people (Cohen and Levinthal 1989). It is often suggested that basic R&D capabilities constitute a firm's absorptive capacity (Cassiman and Veugelers 2006). For business services firms like consultancies (which conduct less R&D, but rely heavily on professional knowledge), this is often indicated by the number of knowledge-intensive jobs (Illeris, 1996). We measure a firm's total number of knowledge-intensive occupations as a percentage of the total number of jobs ($KI.OC_{ij}$). This includes, for manufacturing firms, the number of occupations in research and development and, for business services, the number of occupations in consulting (marketing- and design-related). Other jobs within the firm concern management, facilitating services, purchasing, logistics or production.

We account for the use of face-to-face ($F2F_{ij}$) and information and communication technology (ICT_{ij}) contact by selecting these transfer mechanisms from a survey question on the types of transfer mechanisms used in inter-firm relationships. They are expressed as the sum of all types of transfer mechanisms (personal, written, telephone, e-mail, e-commerce and other types of contact). These variables are direct measurements of how a firm handles its inter-firm relationships by different communication channels. $F2F_{ij}$ is defined as the degree to which it does so by personal contacts, ICT_{ij} by e-mail plus e-commerce contacts.

The external knowledge sources that we take into account are localization, urbanization and Jacobs' externalities. Localization economies are measured by specialization measures for four types of economic sectors: labor-, capital- and knowledge-intensive manufacturing and business services (respectively $SPEC.AI_j$, $SPEC.CI_j$, $SPEC.KI_j$ and $SPEC.KIS_j$). Urbanization economies are measured by a density indicator: the number of total jobs per square kilometer ($DENSITY_j$). Jacobs' externalities are measured by a diversity measure (Gini coefficient; $GINI_j$) that takes into account the employment distribution across all (2-digit NACE sectors; 58 in total) industries in the region. Regions can vary according to whether employment is strongly concentrated in one industry or distributed equally among industries (relative to the national distribution).

Since direct technological-oriented spillover potentials and human capital-related elements are considered as key externalities for productivity and growth, we empirically explicitly focus on the knowledge externalities research and development, innovation and education. Research and development ($R\&D_j$) is measured as the number of employees who undertake R&D activities in the total regional number of regional employment. Innovation (INN_j) is the regional amount of successful innovators in the total population of firms. This indicator concerns the actual innovative output (new products and services) of firms. Both R&D and innovation are drawn from the Netherland's Innovation Communication Survey (CIS-3) (Raspe and Van Oort 2006). The regional educational level (EDU_j) is expressed as the number of highly educated employees (university and higher vocational education) in the total regional employment. This indicator is based on several studies on labor and spatial economics (Glaeser and Shapiro 2003, Crescenzi 2005 and Bils and Klenow 2000), and is used by the OECD (see Temple 2001) to define human capital.

In addition to the knowledge-related determinants, we control in our models for regional growth ($REG.GROWTH_j$) measured by the relative employment growth in the region over the last six years. Spatial investments levels ($INVEST_j$) are measured by investments in immobile capital goods, excluding houses. Industry differences in wages ($WAGE_j$) are measured using the average regional wage level. Newly built business premises ($BUS.SITES_j$) are measured by the growth in business sites in hectares (see also Van Oort 2004). Accessibility ($ACCESAB_j$) of the region is measured by the number of jobs that can be reached by road within 45 minutes. Finally, a dummy for the presence of a university is included.

Where we control for industry fixed effects, we include three industry dummies: AI_{ij}, CI_{ij}, KI_{ij}, respectively representing industry memberships in Labor Intensive Manufacturing, Capital Intensive Manufacturing and Knowledge Intensive Manufacturing (see appendix 5.4 for the NACE-codes of these industries[27]). We use Knowledge Intensive Business Services as reference.

All spatial variables (reflecting opportunities for spatial externalities) draw upon a database that includes all establishments in the Netherlands involved in all types of economic activities (LISA database, see Raspe and Van Oort for elaboration on the data). This database is aggregated to a regional level (128 municipalities, corresponding to cities).

In the models, we include a lagged effect in the relation between the firm's knowledge context and the firm's performance. As put forth by Henderson (2003) it is to be expected that it takes time for knowledge to spill over and get embedded in firms. Following Henderson (2003), we use a three year 'lag' by linking firm productivity in 2005 to variables in the firm's sectoral environment in 2002. Appendix 5.2 shows the descriptive statistics of the variables.

5.5 Empirical results

5.5.1 Econometric estimates

Stemming from the former sections, this paper empirically has two goals. First, we want to show the significance of controlling for firm-specific characteristics while testing for spatial effects. Second, we want to show that existing methodologies can be problematic and that alternative random effect models can provide a comprehensive framework to empirically address the key contextual considerations of the firm embedded in its spatial contexts.

As a first step it is crucial to distinguish the firm-level-compositional source of variation from the regional-contextual ones in order to minimize confounding. The null model (indicating the earlier mentioned intra-class correlation) gives an indication of the part of the variation that can be assigned to regional-specific characteristics. Table 5.1 shows that 2.3% of the firm productivity can be related to its location (and more that 97% to matters of internal organization). Our first

27 Industry-fixed effects control for the fact that there exist differences in productivity between industries. Industry-specific characteristics capture various technology and knowledge dimensions, such as technological opportunity, appropriability regimes, or the emergence of dominant designs along the technology life cycle (Teece, 1986; Breschi et al.. 2000).

conclusion therefore is that 'the region' plays a role but that its impact is minor compared to firm internal factors.

Table 5.1 further presents the models for firm level productivity and independent variables on both the firm and the regional level. The random effect models (models 1a-4a) can be compared with ordinary multiple regression models (OLS-models 1b-3b) to avoid the possible drawbacks of not taking the nested structure of the data into account (the fact that firms share the same spatial context).

Model 1a first shows the results of the firm-specific characteristics we are able to control for. Mainly firm size is significant and positively related to productivity. The larger the firm, the more economies of scale influence firm productivity. These results are in line with many findings in the literature (see Evans 1987 and Caroll and Hannan 2000 for overviews). Model 1a also tests for the age of a firm. Besides age an age-quadratic term is simultaneously included as a proxy for possible lock-in of the oldest firms. We hypothesized that, in general terms, it is to be expected that there is a positive relationship between age and productivity, indicating that firms can learn from their own experience and that successful firms grow and become more efficient (i.e., reduce their costs), while the unsuccessful ones face lower productivity levels. On the other hand, we assume that firm performance tends to decline as the firm evolves over its life cycle (a non-linear relationship between productivity and age). Model 1a shows that age is significant and positive, while age-squared is significant and negative, which confirms our hypothesis.

Model 1a also gives the insight that the effect of 'knowledge-based' variables, like the amount of knowledge intensive occupations, the amount of face-to-face interaction and ICT usage. Contrary to what is often is assumed (that knowledge enhances productivity), we only find a positive effect of ICT usage. The more ICT firms use in their interfirm-relationships, the more productive firms are. These findings are in line with those of recent studies (see Pilat 2004 for an overview), though both our proxies for 'absorptive capacity' and face-to-face interaction are not significant. According to the absorptive capacity indicator, we suggest that the size effect captures part of the impact and not the amount of knowledge-intensive occupations as such (due to multicolliniarity problems, we do not test them simultaneously). While face-to-face interaction is assumed to be important for internalizing tacit knowledge, we do not find that the use of more face-to-face interactions leads to better firm performance. Research in face-to-face as such, though, is complex (McCann and Simonen 2005, Storper and Venables 2004), and in further research it would be interesting, for example, to analyze whether face-to-face interaction is especially important in the beginning of trust-based relations or only in specific types of interactions. This is beyond the scope of this paper, since we are mainly interested in the firm-specific characteristics that influence regional composition.

Specifically focusing on the three explicit spatial knowledge indictors: R&D, innovation and education, we learn that firm productivity can indeed be related to these kinds of external knowledge sources (model 2a). Locally bounded innovation particularly enhances firm productivity. This means that firms profit from being located in a successful innovative region. Here we find indications that proximity to innovators is indeed fruitful. Remarkably, our analyses show that a high intensity of external localized research and development does not enhance firm's productivity. As the literature on spillovers often has a strong focus on these technological spillovers, it is not the research-related knowledge source but the introduction of new products and services to the market that seems to matter. Also, the human capital variable 'education' is not significant. This means that firm productivity is not influenced by the regional amount of highly educated knowledge workers. One of the explanations might be that the highest intensities of the educational variable co-locate with the urbanization (density) variable. Though the correlation between those variables is not too high, one can argue that density captures part of this human capital phenomenon. The urbanization variable is positively significant, meaning that firms are more productive in the most dense and agglomerated part of the landscape. This is in line with the earlier mentioned studies by Ciccone and Hall (1996), Moomaw (1981) and Kim (1997).

Model 3a represents what we are especially seeking: the combination of firm-specific and regional-specific characteristics. This specification indeed shows that while controlling for firm-specific characteristics, the spatial effects (almost completely) fade away. While earlier we were not controlling for these firm characteristics, assigned a considerable part of the fact that 'region matters' to innovation spillovers or externalities, this effect disappears due to the unequal distribution - especially that of firm size - over space. In reality, it is size and not external sources that matters. We conclude that it is important to control for firm-level heterogeneity to reduce the potential upward biases and possible exaggerations of the spatial impact.

Model 4a finally controls for the more traditional localization, urbanization and conventional regional variables that can enhance firm productivity. These variables are not significant in our models, except for the negative impact of the presence of a university. This indicates that firms in regions that inhabit a university are less productive than firms in regions that lack the presence of a university. As proximity to a university is often assumed to have a positive effect, it would be interesting to further explore how and for what types of firms this presence has a positive effect.

Table 5.1 also shows the effect of using random effect models instead of OLS estimations (models 1b-3b are references of 1a-3a). We use the OLS models as a reference for our random effect models because these models represent the disaggregation of higher-level regional data that are assigned into values for a much larger number of subunits (not taking the hierarchical structure in the data into account: the nesting of firms in regions). In these OLS-models, the scores of the regional knowledge factors are assigned to the firm level, which has the potential fallacy to result in spurious significances. We confirm that more traditional methodologies (like OLS) can be problematic for empirically addressing the key contextual considerations of the firm embedded in its spatial contexts. Most striking is the fact that the OLS estimations in the final model (3b) show significant effects for the external knowledge factor innovation, even controlling for firm-level heterogeneity. OLS-modeling estimations would lead to the conclusion that innovation spillovers are highly significant. In our opinion, this is disputable; leading to exaggerations and to liberal assigned significance levels. We conclude that when modeling the relationship between location (and its knowledge characteristics) and firm-level productivity, not taking the hierarchical structure into account potentially leads to a bias in the effect of regional variables. Random effect models better fit these kinds of research questions, which combine firm and spatial characteristics simultaneously.

5.5.2 Further multilevel elaborations

Focusing on the effect of localized knowledge externalities, so far, we analyzed whether within each region there is a positive relationship between localized knowledge externalities and productivity.

Table 5.1 Models on firm level productivity

	FIRM LEVEL PRODUCTIVITY '05							
	Random effect models (Random intercept)					OLS (reference models)		
	Null	Model 1a	Model 2a	Model 3a	Model 4a	Model 1b	Model 2b	Model 3b
Firm								
Constant	10.627***	3.793**	5.737**	0.811	2.849	3.681***	5.486**	0.514
	(0.084)	(0.741)	(2.060)	(2.062)	(2.661)	(0.739)	(1.912)	(1.976)
SIZE		0.423***	-	0.417***	0.420***	0.426***	-	0.417***
		(0.034)		(0.034)	(0.034)	(0.034)		(0.034)
AGE		1.434*	-	1.531*	1.518*	1.482*	-	1.559*
		(0.869)		(0.869)	(0.868)	(0.874)		(0.873)
AGE_SQ		-0.591*	-	-0.625*	-0.622*	-0.606*	-	-0.635**
		(0.323)		(0.323)	(0.322)	(0.325)		(0.324)
KI.OC.		0.003	-	0.003	0.004	-0.001	-	-0.001
		(0.018)		(0.018)	(0.018)	(0.011)		(0.011)
F2F		0.029	-	0.033	0.034	0.028	-	0.034
		(0.027)		(0.027)	(0.027)	(0.027)		(0.027)
ICT		0.066**	-	0.066**	0.067**	0.070**	-	0.067**
		(0.029)		(0.029)	(0.029)	(0.029)		(0.029)
Regional								
SPEC AI			0.215	0.169	0.156		0.222	0.178
			(0.135)	(0.127)	(0.129)		(0.126)	(0.121)
SPEC CI			-0.121	-0.126	-0.102		-0.116	-0.123
			(0.088)	(0.083)	(0.088)		(0.084)	(0.081)
SPEC KI			0.006	-0.021	-0.033		-0.001	-0.031
			(0.085)	(0.079)	(0.081)		(0.077)	(0.074)
DENSITY			0.133*	0.130*	0.182**		0.142**	0.134**
			(0.078)	(0.073)	(0.080)		(0.070)	(0.068)
GINI			-0.084	0.002	-0.005		0.028	0.091
			(0.367)	(0.324)	(0.280)		(0.280)	(0.270)
'EDU'			-3.336	-3.012	-2.310		-3.992**	-3.443*
			(2.098)	(1.986)	(1.968)		(1.939)	(1.892)
'R&D'			0.055	0.106	0.090		0.046	0.106
			(0.119)	(0.111)	(0.129)		(0.109)	(0.106)

		FIRM LEVEL PRODUCTIVITY '05							
		Random effect models (Random intercept)					OLS (reference models)		
		Null	Model 1a	Model 2a	Model 3a	Model 4a	Model 1b	Model 2b	Model 3b
'INN'				1.336*** (0.488)	0.787* (0.459)	0.644 (0.579)		1.453*** (0.450)	0.889** (0.436)
REG.GROW						0.121 (0.891)			
INVEST						0.018 (0.061)			
WAGE						-0.073 (0.095)			
BUS.SITES						-0.023 (0.072)			
ACCESSAB						-0.147 (0.203)			
UNIV						-0.860** (0.430)			
Industry fixed effects		No	Yes	No	Yes	Yes	Yes	No	Yes
-2*loglikelih.		9870.6	9697.9	9855.1	9687.7	9681.0			
R Square	*i*	-	7.7%	-	7.7%	7.7%	8.4%	1.2%	9.1%
	j		48.0%	64.3%	79.5%	99%	-		
Intraclass		2.3%							

Standard deviation between parentheses, *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.10 level.
Robustness checks: Industry, Agglomeration, Time. In our models, we tested for specifications of industry, agglomeration and time-fixed effects. We tested for industry fixed effects, making a distinction in Labor, Capital and Knowledge intensive manufacturing and Business Services. Dummy coefficients are not included in the table. We also tested for regional fixed effects: whether a location in one of the eight Daily Urban Systems has an extra contribution on productivity. Models including specifications of this higher spatial level (agglomeration) were insignificant and showed no model improvements. The last robustness test was for potential disturbances due to time influences (market conditions/economic climate). Our data allow us to test cross-sections of the years 2000 and 2005 (and the average productivity in this period). All directions and significance levels of the coefficients in the models are the same for models of 2000, 2005, and the average in this period. We chose to show the 2005 models. Variance explained Knowing that there is a contextual effect for firm's productivity and that firm internal characteristics are dominant, the question remains: 'how much variance is explained?' In multilevel regression analysis, the issue of modeled or explained variance as test statistic is complex. It can be estimated by examining the residual error variances in a sequence of models where the null model is the baseline model. This must be issued level by level (Hox 2002). For our models, we see that the proportion of variance explained at the firm level is 7.7%. Model 2a shows that although no level 2 variables are added, 48% of the municipal-level variance is explained by the firm's internal characteristics. If the proportion of, for example, size and sector are not exactly the same in all regions, the regions differ in the average size or sectors of their firms; this variation can explain some of the variance in average productivity between regions. In model 3a, we see that adding regional knowledge factors raises the R-squared by almost 15%-points (to 79.5%)

However, this relationship might not be a fixed relationship over all regions (fixed meaning that it does not vary over regions). Interesting for further research would be to explore which firm-specific characteristics, like its size, age, industry etc., can profit more than others. Or, if we did not find a relationship between localized knowledge externalities (as in the case of research and development), it might be the case that this relationship in general terms does not appear but that only some type of firms (for example, the knowledge-intensive or smallest ones) profit from these externalities.

Analyzing these kinds of effects provides what are called 'cross-level interaction effects'; interactions between variables measured at hierarchically structured data on different levels (see Kreft & de Leeuw 2004, Hox 2002). These effects can be tested for all firm-level variables. The first step is the estimation of *random coefficient models* in which the slope of any of the explanatory variables on the micro level has a significant variance component between the regions. According to our analysis, it appears that especially firm size has a significant slope variance.[28]

When analyzing the 'cross-level interaction effect' between firm size and regional externalities, we find that the covariance between the region's intercept and its slope is negative. This negative covariance suggests that a higher intercept is associated with a lower slope. In other words, larger firms are less productive in some regions, or their smaller counterpart firms are more productive in some regions. The question now is whether localized knowledge externalities do influence this relationship. What we find is that especially the interaction-effect between firm size and innovation externalities is significant. This means that in the relationship between localized knowledge externalities and productivity, firm size actually plays an important role. As this interaction variable is negative, we find indications that smaller firms and not larger firms especially profit from spatially bounded innovation externalities. In the last section we concluded that it is very important to control for firm-level heterogeneity, while investigating the 'role of the region' and not controlling leads to potential upward biases and possible exaggerations of the spatial impact. Now we see that is also important to specify within this firm level heterogeneity. When we do not find generalized effects for all firms, the firm-region (or micro-macro) relationship can differ according to firm-specific characteristics. We found such an effect for firm size.

5.6 Conclusions

Geographers and regional scientists over the years have provided us with a large body of literature on growth and productivity-enhancing (localized) knowledge externalities, stressing that: 'the region matters'. Recently, critical authors have claimed that while the empirical evidence about the linkages between regionally bounded advantages and growth are focused on the regional and local levels, the relationship should actually and most profoundly hold at the micro- or firm level. Too little is known about the locational impact on firm performance because of limitations in both the conceptualization of the linkage between regions and firms as well as limitations in data availability.

28 We also tested for random slopes of two-digit industry membership (NACE codes). It turns out that textile (fabrics) manufacturing (NACE 17), Chemical products manufacturing (NACE 24) and Research and Development (NACE 73) have significant slopes. This means that firms active in these economic activities are sensitive for regional externalities. For further research, it would be interesting to test which externalities foster the performance of firms in these industries.

In this paper, we try to contribute to the better understanding of the nature of the relationship between 'the firm' and 'the region'. This means that we had a strong focus on 'the firm' as a central actor, allowing greater roles for firm-specific characteristics while analyzing the impact of economic advantages of regions. This also implies the use of alternative methods that acknowledge the multilevel structure of regional advantages and avoids potential estimation biases due to well-known ecological and atomistic fallacies. Empirically, we illustrated that 'more firm conceptualization and testing in geography' should not be reduced to micro analysis in which regional variables are simply linked to the micro actors and that multilevel models can provide a comprehensive framework to empirically address the key contextual considerations of the firm embedded in its contexts. This modeling technique respects the conceptual multi-layered issues involved and enables us to model firm-level productivity simultaneously with firm's knowledge intensive geographical context.

We found a spatial effect fostering firm productivity; the region contributes almost 2.5% to productivity at the firm level. The region matters, one can say. Analyzing what kinds of externalities contribute to this spatial impact, we found that external innovation sources in particular enhance individual firm productivity. On the other hand, this effect turns out to be a composition effect due to firm-specific characteristics, mainly firm size and type of industrial activities. We therefore conclude that seriously testing regional economic advantages requires the allowance of firm-specific characteristics. Otherwise, 'the role of the region' can be blurred and exaggerated.

The relationship between the firm and its spatial context, though, is even more complex, as we find that this differs for these firm-specific characteristics. We find that mainly smaller firms and not their larger counterparts benefit from localized knowledge externalities. Not allowing for these kinds of firm-specific characteristics will potentially overlook these kinds of cross-level interactions.

In addition to the inclusion of firm-specific characteristics and a stronger focus on 'the firm' as a central actor in geographical analysis, we also tried to show the importance of incorporating a multilevel (hierarchical) structure instead of single-level analysis. We showed that single-level approaches (like OLS models) would lead to the conclusion that innovation spillovers are highly significant. In our opinion, to do so is disputable this would lead to exaggerations and to liberally assigned significance levels. Multilevel effect models better fit research questions that combine firm and spatial characteristics simultaneously.

5.6.1 Policy recommendations

Studies that give full insight in firm-specific characteristics combined with variation in their spatial contexts are scarce. The presented insights, though, are important for policymakers aiming at economic development by geographical policy investments. We showed that the regional innovation policies seem more effective when aimed at smaller firms instead of at larger ones. Especially for smaller firms, one can argue that they can leverage their own knowledge capital by standing on the shoulders of giants and that they profit more from local knowledge transfers. In addition, the type of economic activity matters in this context, though we did not extensively elaborate on this issue. Further research should give more insight into the (type of) cross-level interaction effects between certain economic activities and their regional context. For instance, why do firms active in research and development profit more in certain regions than do firms doing the same kind of work elsewhere? This indicates that heterogeneous processes at the firm and regional levels may not align with those of regional planners hoping to develop innovative and high-performance regions in general terms. For now, we conclude that regional economic strategies should take into account these industrial organization aspects in their fine tuning, since the firm-context interaction turns out to be a complex one depending on both firm-specific and region-specific characteristics. There is a need to tailor policy efforts to suit this heterogeneity. In this paper, we showed that multilevel analyses provide a fruitful tool to help analyze cross-level interaction effects, taking firm and regional-specific characteristics simultaneously into account.

We additionally recommend that regional innovation policies broaden their perspective by not only focusing on R&D but also on the actual innovative success. We showed that those regions where successful innovators are clustered and not the regions with the highest intensities of research and development activity or other more conventional externalities (which is often aimed at by policy makers) contain potential innovation spillovers.

5.6.2 Limitations and some suggestions for further research

At several points in the paper, we suggested areas for further research. These suggestions have to do with (1) the type of variables used and (2) the exploration of cross-level interaction effects. First, we were limited in the number and type of firm-level variables. As our models show, we can explain about 10% of firm productivity using the firm variables we used. This means that there is a lot to gain in measuring other firm-level aspects that have to do with productivity. More organizational competences and strategies can be included in this research. In a related area, it would be interesting to further explore how to measure and include 'competence, resource and knowledge'-related aspects. This fits the line of research on the 'resource of knowledge-based view of the firm' (Foss 1998, Grant 1996). An example would be an examination of absorptive capacity and face-to-face interaction. Second, we indicated that it might be the case that not all firms but only specific ones profit from certain regional conditions (we showed, for example, the case of small firms or firms in certain types of economic industries). An exciting line of research that can be analyzed with multilevel analysis centers on the question: what types of firms (profit) in what types of contexts? This can fulfill the further exploration of the interaction between firm-specific and regional-specific characteristics and can further bring together firm-level analysts and regional scientists.

Appendix 5.1 Multilevel models

Hox (2002) and Goldstein (2003) provide introductions to random effect regression modeling. The model assumes that we have data from J groups, with a different number of respondents n_j in each group. On the respondent level, we have the outcome of respondent i in group j, variable Y_{ij}. There is an explanatory variable X_{ij} on the respondent level and one group-level explanatory variable Z_j. To model these data, a separate regression model in each group is formulated:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij} \qquad (5.3)$$

The variation of the regression coefficients is modeled by a group-level regression model:

$$\beta_{ij} = \gamma_{00} + \gamma_{01} Z_j + \mu_{0j} \qquad (5.4)$$

and

$$\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + \mu_{1j} \qquad (5.5)$$

The individual-level residuals e_{ij} are assumed to have a normal distribution with mean zero and variance σ^2_e. The group-level residuals μ_{0j} + μ_{1j} are assumed to have a multivariate normal distribution with an expected value of zero, and they are assumed to be independent from the residual errors e_{ij}. The variance of the residual errors μ_{0j} is specified as σ^2_e and the variance of the residual errors μ_{0j} and μ_{1j} is specified as $\sigma^2_{\mu 0}$ and $\sigma^2_{\mu 1}$. Hox (2002) write this model as a single regression model by substituting Equations (5.4) and (5.5) into equation (5.3). Substitution and rearranging terms gives:

$$Y_{ij} = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j + \mu_{0j} + \mu_{1j} X_{ij} + e_{ij} \qquad (5.6)$$

The segment $\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j$ in Equation 4 contains all the fixed coefficients; it is the fixed (or deterministic) part of the model. The segment $\mu_{0j} + \mu_{1j} X_{ij} + e_{ij}$ in Equation 5.6 contains all the random error terms; it is the random (or stochastic) part of the model. The term $X_{ij} Z_j$ is an interaction term that appears in the model because of modeling the varying regression slope β_{1j} of the respondent-level variable X_{ij} with the group level variable Z_j.

Even if the analysis includes only variables at the lowest (individual) level, standard multivariate models are not appropriate. Multilevel models are needed because grouped data violate the assumption of independence of all observations. The amount of dependence can be expressed as the intra-class correlation (ICC), ρ. In the random effect model , the ICC is estimated by specifying an empty model, as follows:

$$Y_{ij} = \gamma_{00} + \mu_{0j} + e_{ij} \qquad (5.7)$$

This model does not explain any variance in Y. It only decomposes the variance of Y into two independent components σ^2_e, which is the variance of the lowest-level errors e_{ij}, and $\sigma^2_{\mu 0}$, which is the variance of the highest-level errors μ_{0j}. Using this model, the (ICC) ρ is given by the equation:

$$\rho = \sigma^2_{\mu 0} / (\sigma^2_{\mu 0} + \sigma^2_e) \qquad (5.8)$$

Our outcome variable Y_{ij} is the firm performance, measured as productivity. In the regression line (5.3) β_{0j} is the usual intercept, β_{1j} is the usual regression coefficient (slope) for the explanatory variable, and e_{ij} is the usual residual error term. The subscript *j* is for the region, and the subscript *i* is for individual firms. The difference with a usual regression model is that we assume that each region *j* has a different intercept coefficient β_{0j} and a different slope coefficient β_{1j} (since the intercept and slope vary across the regions they are often referred to as random coefficients; see Hox 2002).

Appendix 5.2 Survey

A random stratified sample, taking firm size, sector and region into account, was taken from the LISA database (an employment register of all Dutch economic establishments, see Van Oort et al. 2006). For this research, we included only firms in manufacturing and business services and firms with more than 1 employee. The response was approximately 7% (representative for the stratification by region, size and sector). Table 5.2 summarizes the population, survey and response.

Table 5.2 Population, survey and response

	# Municipalities	population	survey	response	response %
Region Amsterdam	16	17.141	5.980	399	6.7%
Region Rotterdam	28	9.710	4.818	357	7.4%
Region Groningen	12	2.720	2.128	167	7.8%
Region Eindhoven	16	6.287	3.763	289	7.7%
Region Apeldoorn/Deventer/Zutphen	14	3.204	2.217	162	7.3%
Region Arnhem-Nijmegen	24	5.324	3.259	271	8.3%
Region The Hague	13	4.921	3.117	185	5.9%
Region Utrecht	13	5.486	3.355	179	5.3%
TOTAL	136	54,792	28,637	2,009	7.0%

Appendix 5.3 Descriptive statistics and correlations

Table 5.3 Descriptive Statistics (log transformed)

	Min	Max	Mean	St.dev.
SIZE	-9.21	20.91	13.83	1.87
AGE	0.00	1.95	1.77	0.33
AGE_SQ	0.00	3.79	3.24	0.89
KI.OC.	-9.21	4.61	-0.66	5.52
F2F	-6.91	4.61	3.01	2.28
ICT	-6.91	4.61	3.23	2.08
AI	0.00	1.00	0.12	0.33
CI	0.00	1.00	0.07	0.25
KI	0.00	1.00	0.12	0.33
SPEC AI	-9.21	-1.67	-3.69	1.07
SPEC CI	-9.21	-1.09	-4.02	1.37
SPEC KI	-9.21	-1.58	-3.74	1.38
DENSITY	3.01	8.03	5.29	1.08
GINI	-0.81	0.16	-0.70	0.11
'EDU'	0.16	0.42	0.26	0.05
'R&D'	-1.70	2.36	-0.01	0.76
'INN'	3.22	4.40	3.94	0.21
REG.GROW	0.85	1.28	1.03	0.08
INVEST	-2.99	5.57	0.04	1.00
WAGE	-2.99	3.10	-0.15	0.93
BUS.SITES	-1.88	4.48	-0.03	1.09
ACCESSAB	12.75	15.03	14.10	0.58
UNIV	0.00	1.00	0.07	0.26

Table 5.4 Correlation matrix of firm-level independent variables

	1	2	3	4	5	6
SIZE	1.00	0.18	0.20	0.02	-0.05	0.03
AGE	0.18	1.00	0.98	-0.05	0.00	-0.02
AGE_SQ	0.20	0.98	1.00	-0.06	0.00	-0.01
KI.OC.	0.02	-0.05	-0.06	1.00	0.04	0.06
F2F	-0.05	0.00	0.00	0.04	1.00	0.08
ICT	0.03	-0.02	-0.01	0.06	0.08	1.00

Table 5.5 Correlation matrix of regional-level independent variables

	1	v2	3	4	5	6	7	8	9	10	11	12	13	14
SPEC AI	1.00	0.54	0.52	-0.20	-0.14	-0.51	0.13	-0.02	0.01	0.03	0.22	-0.10	-0.21	-0.06
SPEC CI	0.54	1.00	0.40	-0.18	-0.15	-0.42	0.13	0.18	0.08	-0.12	0.36	-0.20	-0.18	-0.08
SPEC KI	0.52	0.40	1.00	0.03	-0.13	-0.23	0.29	0.33	0.07	0.01	0.25	-0.14	-0.09	0.01
DENSITY	-0.20	-0.18	0.03	1.00	0.17	0.30	0.07	0.33	-0.17	0.02	-0.24	-0.17	0.26	0.20
GINI	-0.14	-0.15	-0.13	0.17	1.00	0.21	-0.12	0.07	-0.11	0.10	-0.05	0.00	0.16	0.50
'EDU'	-0.51	-0.42	-0.23	0.30	0.21	1.00	0.16	0.12	-0.11	-0.13	-0.11	-0.07	0.23	0.49
'R&D'	0.13	0.13	0.29	0.07	-0.12	0.16	1.00	0.33	-0.06	-0.15	0.12	-0.11	-0.19	0.23
'INN'	-0.02	0.18	0.33	0.33	0.07	0.12	0.33	1.00	-0.09	-0.19	-0.09	-0.22	0.46	0.14
REG.GROW	0.01	0.08	0.07	-0.17	-0.11	-0.11	-0.06	-0.09	1.00	0.07	0.12	0.07	0.05	-0.06
INVEST	0.03	-0.12	0.01	0.02	0.10	-0.13	-0.15	-0.19	0.07	1.00	-0.03	0.10	-0.09	-0.02
WAGE	0.22	0.36	0.25	-0.24	-0.05	-0.11	0.12	-0.09	0.12	-0.03	1.00	-0.12	-0.17	0.02
BUS.SITES	-0.10	-0.20	-0.14	-0.17	0.00	-0.07	-0.11	-0.22	0.07	0.10	-0.12	1.00	-0.10	0.01
ACCESSAB	-0.21	-0.18	-0.09	0.26	0.16	0.23	-0.19	0.46	0.05	-0.09	-0.17	-0.10	1.00	0.06
UNIV	-0.06	-0.08	0.01	0.20	0.50	0.49	0.23	0.14	-0.06	-0.02	0.02	0.01	0.06	1.00

Appendix 5.4 NACE codes

Production activities are aggregated from four sub-categories. The distinction in these four appears initially important for knowledge economic analysis. Two dimensions are used to categorize the four initial industrial branches: their respective degree of knowledge- and capital intensity (Van Oort, 2004). First, labor-intensive production shows low scores on either of two indicators. Firms in these industries are characterized as traditional and craft oriented. Second, capital-intensive industries transform large amounts of physical inputs into products, using large-scale and capital-intensive production processes. Usually, firms in these categories are large space consumers and are dependent on the physical delivery of inputs (and thus infrastructure). Third, the knowledge-intensive process industry has the same characteristics but at the same time has a large tendency towards technological dependency and innovation. The petrochemical industries in the Rotterdam harbor area form important examples of this category of firms in the South Holland region. Fourth, knowledge-intensive production incorporates modern, medium- to high technology firms in which knowledge, qualified employees and research & development form important components of the production process.

Table 5.6 Sector and NACE-codes

SECTORS (based on 2 digit NACE-codes)
Labor intensive manufacturing
17, 18, 19, 20, 28, 36, 37
Capital intensive manufacturing
15, 16, 21, 25, 26
Knowledge intensive manufacturing
23, 24, 27, 29, 30, 31, 32, 33, 34, 35
Knowledge services
22, 64, 65, 66, 67, 70, 71, 72, 73, 74

6 Firm performance in knowledge regions[29]

Abstract

Over the years, several scholars have argued in favor of territorial knowledge concepts, like 'learning regions'. One of the main criticisms, though, is that these concepts lack empirical operationalization, especially since 'the firm' as a research unit is underdeveloped. We contribute to the need for empirically grounded research that contributes to a better understanding of the spatial knowledge conditions that shape economic development on the firm. First we elaborate on why we deal with an intrinsic multilevel problem. Then we test some of the underlying hypotheses of territorial knowledge concepts by multilevel modeling. We find that 'location' matters for firm productivity. In particular, proximity to successful innovators turns out to be important. Firm-specific characteristics (especially size), though, play an important conditioning role that link firms to regions.

6.1 Introduction

It has become commonplace among policymakers as well as increasingly popular among economic scientists to claim that knowledge and learning are explicit and crucial factors for generating sustained economic growth. 'Economic geography' has contributed to this field of research over the years by stressing that knowledge does not diffuse instantaneously and that the geographical dimension and proximity are crucial to knowledge diffusion (Döring and Schnellenbach 2006). From this perspective, localized concepts capturing knowledge and learning have been developed. In the early 1990s, the term learning region surfaced in the literature. The ability of firms to innovate and learn is of crucial importance for competitive survival, and the region is seen as a relevant context for this. In this line of argument, Richard Florida is often cited: 'regions are becoming focal points for knowledge creation and learning in the new age of global, knowledge-intensive capitalism, as they in effect become learning regions. These learning regions function as collectors and repositories of knowledge and ideas, and provide the underlying environment of infrastructure which facilitates the flow of knowledge, ideas and learning. In fact, despite continued predictions of the end of geography, regions are becoming more important modes of economic and technological organization on a globe scale (Florida 1995: 527)'.

Over the years, several scholars have argued in favor of this concept (Asheim 1996, Morgan 1997, Cooke 2001, Rutten and Boekema 2007). However, the concept of the 'learning region' has also been confronted with criticism. One of the main criticisms is that the concept lacks empirical operationalization and therefore becomes 'fuzzy' (Markusen 1999, MacKinnon et al. 2002). Whether 'learning regions' are more than 'just' a proposition has been questioned, especially since 'the firm' (the driver for innovation and economic growth) as a research unit is underdeveloped in it (Maskell 2001, Taylor and Asheim 2002). In line with this criticism, one can argue that there is a strong

29 Raspe, O. and F.G. van Oort. Firm performance in knowledge regions, manuscript resubmitted for publication.

need for empirically grounded research that contributes to a better understanding of the spatial knowledge and learning conditions that shape economic development, especially on the level of the firm (Boschma 2004).

In this paper, we try to address this need. We start from the premise that the relationship between spatially bounded knowledge circumstances and economic performance should actually and most profoundly hold at the micro or firm levels (Audretsch et al. 2006, Beugelsdijk 2007). This means that we deal with an intrinsic multilevel problem that concerns relationships between variables that are measured at a number of different hierarchical levels, including 'the firm' (micro level) and 'the region' (macro level) (Hox 2002). Possible relationships in a multilevel framework include macro variables influencing macro variables, micro variables influencing micro variables, macro variables influencing micro variables and vice versa, and micro-micro relationships varying interactively with macro variables. We argue that the macro-micro interaction is especially interesting from a 'learning region' perspective (Malmberg 1997) for two reasons. First, regional knowledge circumstances (might) impact firm-level performance (once firm-specific characteristics have been controlled for). For example, firms can profit from the presence of nearby external knowledge sources, such as a university or research laboratory. Second, relationships on the level of the firm (might) vary interactively with these regional knowledge circumstances (so-called cross-level interaction effects). This means that the impact of 'localized knowledge circumstances' varies across firms within the same location and should not be treated as a location-specific externality for all firms in a region (Duncan et al. 1998). In this paper, we will elaborate on this multilevel problem from a knowledge-based perspective and empirically test some of the underlying hypotheses of territorial knowledge concepts. We use data at the establishment level simultaneously with agglomerated knowledge variables to build this empirical model. Our research question concerns how firm-specific characteristics and localized knowledge sources are mutually and simultaneously related to economic performance processes at the firm level.

There are limitations to our empirical approach. We focus on spatially bounded externalities as a pre-condition for knowledge flows instead of measuring knowledge spillovers or network interaction directly. As such, we are neither able to determine whether knowledge actually spills from source to receiver, nor can we exclude market exchanges of knowledge that require physical proximity. We can conclude on the question of whether 'the region' indeed matters (and what the size of its impact is), what it is 'in the region' that provides vital supplements for firm performance and what firm internal characteristics precondition profiting from location. We find that 'location' matters for firm productivity. In particular, proximity to successful innovators turns out to be important. This is not a technological R&D-related spillover effect, but a more generalized cluster effect that stems from proximity to external sources related to the successful introduction of new products or services to the market. Firm size thereby plays an important conditioning role, as we find that smaller firms (which are less able to invest in knowledge sources themselves), but not their larger counterparts, profit from spatially bounded innovation externalities. We also find that industry characteristics are more important for productivity differences than firm internal knowledge characteristics that indicate a firm's internal knowledge base (so-called absorptive capacity).

The paper is organized as follows. The next section argues that focusing on firms in concepts like 'learning regions' is a task that is intrinsically multilevel in nature. We elaborate on why we approach it as such and indicate what firm internal and external factors are relevant to incorporate in empirical testing. Section 6.3 deals with multilevel modeling and introduces the data and variables used in the analysis. Section 6.4 presents the empirical results of our multilevel models that simultaneously and interactively model firm internal and external factors. In the last section, we conclude by discussing our findings and relating them to policy recommendations.

6.2 An intrinsic multilevel problem

In our multilevel perspective, we consider the firm as the relevant 'phenotype': that is, the unit to which economic selection applies its grip and in which adaptation is embodied (Nooteboom 1999). Conceptually, we embed our analysis in the 'resource-based view of the firm' (Taylor and Asheim 2001 and Maskell 2001), which provides a comprehensive firm-based framework for analyzing firm-regional interactions. According to this view, a firm is a bundle or collection of unique resources, competences and capabilities, and those with superior ones will earn rents. This view suggests that firm capabilities that are valuable, rare and inimitable will determine long-term competitive advantage (this perspective is based on Penrose 1959 and was later elaborated by Teece 1982). While until recently the potential of competence-based thinking within geography has been stressed, this thinking has a long tradition in (strategic) management science (Foss 1998, Maskell 2001, Barney et al. 2001). Recently within this research discipline, it has been argued that knowledge should be considered as the most important strategic resource of a firm (Grant 1996, Decarolis and Deeds 1999, Nonaka et al. 2000). Heterogeneous knowledge bases (with special properties) and capabilities among firms are hypothesized as the main determinants of sustained competitive advantage and superior corporate performance (Kaplan and Schenkel 2001).

Firms strive to make their capabilities valuable, rare, inimitable, and non-substitutable in order to protect their sources of competitive advantage against resource imitation, transfer, or substitution. More and more it is argued, though, that there are potential beneficial factors that are not (completely) internal to the individual firm but (also) lie outside its boundaries. The extension of the resource-based view of the firm with 'externalities' has therefore been called for (Lavie 2006, Arya and Lin 2007). Micro-economic advantages come from leveraging knowledge flows in a complex network of relationships. The key premise of the knowledge-based approach is that no one firm can have all of the required capabilities inside its corporate boundaries (Venkatraman and Subramaniam 2001).[30] Arguments of collective learning (Foss 1999) and learning-by-interacting (Lundvall 1992) come to the fore as externalities that inhabit intangible aspects of knowledge sharing. The social complexity and tacitness bind interacting firms together.

Inter-firm relations are not only driven by motives of acquiring knowledge (the learning motives), but also by accessing the knowledge resources of other firms (Grant and Baden-Fuller 2004). While the first motive can tend to converge as each partner learns from the other (due to 'competition for learning': a firm seeks to learn at a faster rate than its partner in order to achieve a positive balance of trade in knowledge), the second motive stresses that partners in inter-firm relations will maintain, and possibly increase, their knowledge specialization. If production requires the combination of many different types of specialized knowledge, then efficiency in knowledge application depends upon, first, the ability to integrate many different types of knowledge and,

30 Venkatraman and Subramaniam (2001) call these economies of expertise.

second, the ability to utilize knowledge to its full capacity (Grant and Baden-Fuller 2004). From a knowledge accessing and integration perspective, inter-firm relations can be logical extensions of a firm's boundaries since products and services require a broad range of different knowledge types.

While the knowledge-based view of the firm gives arguments that knowledge relations are important for firm performance, concepts like the 'learning region' stress the geographical perspective: regional embeddedness and proximity play important roles in facilitating knowledge transfers. The territorial innovation literature adds that within regions, formal, traded and intended spillovers (Grosman and Helpman 1991, Geroski 1995, Moen 2005) are efficiently facilitated, but so are informal networking and untraded interdependencies (Dahl and Pedersen 2004, Manski 2000, Storper 1997, Schrader 1991 and Jovanovic and Rob 1989). Co-location is especially important because it provides a low-cost way for new ideas and talent to make their way into existing activities by facilitating access for newcomers and by lowering the costs of evaluation on the part of those already in the relevant loops. New relationships are hence made easier, cheaper and much more effective than they would be without co-location (Storper and Venables 2004). In relation to the knowledge-based view of the firm, this is interpreted as firms being furnished with valuable heterogeneity using specific factors in their surroundings that are not equally available to competitors located elsewhere.

6.2.1 Firm-specific characteristics

Certain firm-specific characteristics are suggested to be relevant for the interaction with spatially bounded externalities. Both firm and regional characteristics are expected to enhance firm-level performance, and firm-specific characteristics also function as important controls to determine the 'pure' impact of the spatial variables. Second, relationships on the level of the firm (might) vary interactively with these regional knowledge circumstances. This means that micro-micro relationships work out differently according to their spatial context.

There are several firm-specific characteristics that are relevant to our multilevel framework. First, forthcoming from the knowledge-based view of the firm, the firm's internal knowledge base is important for its performance. In particular, the literature on the concept of absorptive capacity indicates that firms require a set of internal strengths, in terms of both understanding where the potential sources of knowledge reside and the ability to absorb and deploy external knowledge. Cohen and Levinthal (1990) indicated that firms must develop an internal core knowledge base so that they can understand external knowledge and know how to apply it to their specific needs. Internal competencies here pre-condition the ability to identify, assimilate and apply for commercial purposes know-how generated outside one's own organization.

Second, linked to the concept of absorptive capacity, transfer mechanisms like face-to-face interaction are often mentioned. Interaction between firms is considered to be fostered by face-to-face interactions, especially where it deals with tacit knowledge, trust-based relationships and frequent contacts. This argues in favor of proximity (Glaeser 1999, McCann and Simonen 2005). Especially, the information used by innovators has a tacit component; such information is often is difficult to set down in blueprints or to codify completely, and hence it is difficult to communicate at a distance. Bathelt et al. (2006) combined the importance of both face-to-face interaction and ICT networking in the proposition of 'local buzz and global pipelines'. They argued that the coexistence of high levels of local (tacit-based) interaction and many above-regional relationships (pipelines) may provide firms located in outward-looking and lively clusters with a string of particular advantages not available to outsiders. Face-to-face interaction here is often indicated as pre-conditioning for local tacit knowledge exchange, while ICT usage is less dominant for local interaction, but as such important for efficient working processes and linking to externalities.

Third, the literature indicates more traditional (industrial organization) elements that can be related to firm performance. In particular, firm size and age have proven to be important (see Audretsch and Dohse 2007 for an overview of this literature). Firm size (representing scale advantages) can be positively related to productivity. Specifically related to externalities, it can be argued that large firms have more opportunities than their smaller counterparts to do research and development activities or to invest in knowledge sources themselves. A small firm wanting to generate its own knowledge capital will be limited by scale and time. Instead, the use of external knowledge and ideas can leverage a small firm's own knowledge capital by standing on the shoulders of giants (Acs et al. 2004, Audretsch et al. 2006). One can therefore argue that small(er) firms especially need local knowledge transfers. This line of reasoning may run counter to the arguments of 'absorptive capacity' as one can argue that firms without any major internal competencies or valuable resources (i.e., small firms) can survive and thrive if they are favorably located, just as the competitiveness of otherwise identical firms may diverge as a consequence of the way in which differences in location show up in their strategies (Maskell 2001).

Also, the age of a firm is hypothesized to be positively related to its productivity. Age can be interpreted as indicating the experience firms have, for instance, in learning from their own experience (Jovanovic 1982). Older firms therefore have less need to tap into external knowledge flows than do new firms. New firms especially exploit the opportunities provided by knowledge and ideas that are not fully commercialized by incumbent firms. According to Acs et al. (2004) and Audretsch et al. (2006), the growth of new firms is the missing link between investments in knowledge and economic growth. It has also been suggested that new firms, more than incumbent ones, profit from knowledge spillovers to contribute to economic growth. Acs and Plummer (2005) argued that this occurs because while new firms – despite their liabilities – tend to introduce the truly novel and unique advances in products and processes, it is entrepreneurs and the firms they found that allow spillovers to make their greatest economic contribution.

This fits with views of ossification of routines and learning processes, indicating that firm performance and external interaction tend to decline as the firm evolves over its life cycle (Audretsch and Dohse 2007).

On the other hand, it has been argued that an 'old' firm might suffer from 'lock-in'. This lock-in can be described as the competency trap: becoming quite good at doing any one thing reduces an organization's capacity to absorb new ideas and to do other things (Levitt and March 1996). It often turns out to be difficult to unlearn habits and routines that have been successful in the past but have become redundant over time (Boschma 2004). Age can also be a proxy for this lock-in process.[31]

31 The literature does not provide clear suggestions concerning at what age lock-in might occur. Often in empirical models, therefore, squared variables are introduced besides age as such. We elaborate on this point in the empirical section.

Fourth, the type of industry is also relevant for firm performance since industries experience different development paths and cyclical influences (Griliches 1979). Industry-specific characteristics capture various technology and knowledge dimensions, such as technological opportunity, appropriability regimes, or the emergence of dominant designs along the technology life cycle (Teece 1986, Breschi et al. 2000). However, firms in some industries benefit more from geographical circumstances than their counterparts in other industries (Henderson 2003). In particular, firms in more knowledge-intensive industries (like high-tech firms) have more incentives to absorb externalities than do firms in less knowledge-intensive industries (Audretsch and Dohse 2007).[32]

Finally, without trying to be exclusive, the literature indicates that product specifications are relevant for external interaction (Grant and Baden-Fuller 2004). Among others, products and services are distinctive in being standard, custom-made or specifically designed or even co-produced (including risk-sharing) in relation to their customers. As economies stemming from the knowledge intensity of the customer relations matter as such, one could argue that the more knowledge intense the customization is, the more proximity matters.

Interesting in relation to our research question is that the suggestions on firm-region interaction above are still part of a lively debate and not yet fully matured. For us, this is even more reason to empirically test some of the above suggestions.

6.2.2 External economies

In this section, we describe the spatially bounded externalities that might matter for firm performance. Particularly, the regional science literature has a strong research tradition in these external economies since, especially in cities, agglomerations and concentrated clusters of these kinds of external economies occur. So-called agglomeration economies can be divided into localization and urbanization economies and Jacobs externalities (Frenken et al. 2007). Localization economies are externalities available to all local firms within the same sector. They usually take the form of what are called Marshallian (technical) externalities, whereby the productivity of labor in a given sector in a given city is assumed to increase with total employment in that sector. These externalities arise from three sources: labor market pooling, the creation of specialized suppliers, and the emergence of knowledge spillovers. Urbanization economies are external economies available to all local firms irrespective of sector and arising from urban size and density. These reflect external economies passed to enterprises as a result of savings from the large-scale operation of the agglomeration or city as a whole and independent of industry structure. Relatively more populous localities are also more likely to house universities, industry research laboratories, trade associations and other knowledge generating organizations. Jacobs' externalities are external economies available to all local firms from a variety of sectors. The diverse industry mix in an urbanized locality also improves the opportunities to interact, copy, modify, and recombine ideas, practices and technologies across industries.

32 The literature also indicates an interesting debate concerning industry specifics and firm size in relation to 'absorptive capacity'. For instance, it has been questioned whether 'industry', typically differentiating in knowledge turbulence (Escribano et al. 2009), or 'size' (Maskell 2001) capture a large part of a firm's absorptive capacity, dominating characteristics related to firm internal knowledge intensities.

These types of economies (localization, urbanization and Jacobs) define externalities stemming from knowledge only implicitly; they do not directly measure technological and production-oriented spillover potentials or human capital-related elements. These latter have especially been indicated as important in studies by Feldman and Audretsch (1999), Glaeser et al. (1992) and Storper and Venables (2004).

Concerning technological spillovers, traditionally most attention has been paid to research and development (R&D) in this context (Black 2004). Investments in R&D or employment related to these research activities are generally considered to be important for productivity and growth. In line with the work of Arrow (1962) and Griliches (1979), over the years a large body of empirical work has found a strong and positive relationship between R&D on the one hand and innovative outputs on the other hand (Audretsch 2003). This was extended by, for example, Jaffe (1989, et al. 1993) and Mansfield (1995), who - as pioneers in the field of technological spillovers - stated that the productivity of a firm's own research may be affected by the size of the pool or pools it can draw upon. Research and development external to a firm can function as input for other firms.

The literature also stresses that ultimately innovation is generally regarded as an important driver of economic and employment growth. As innovation can be defined as the successful introduction of new products (or services) to the market, this is not the same as R&D. Not all trial and error processes lead to new products, and not all new products have a long tradition in R&D activities. While innovation is an outcome of research findings (in the case of manufacturing firms) and is therefore shown in new products, it also includes new services (mainly in the case of business services firms). Often the distinction between technical and non-technical innovations is made. While technical innovations relate to new products and production processes, non-technical innovations concern management, organization and services. Innovation can be related to a firm's own investments and to external elements. In part, it can also result from the imitation of products and services competitors bring to the market.

A third external knowledge source is human capital. Lucas (1988) and Mathur (1999) argued that education is a particularly crucial feature of the knowledge economy. A well-educated workforce has ample opportunities to absorb and use information. Besides the direct effect of the level of education on economic output, human capital also has spillover potential. Human capital externalities may arise if the presence of educated workers makes other workers more productive. If externalities exist, we should see that plants located in cities with high levels of human capital can produce more output with the same inputs than otherwise similar plants located in cities with low levels of human capital (Moretti 2004). Empirical studies by Moretti (2004) and Wheeler (2007) indeed found such effects.

Recently, Florida (2002) identified creative capital, embodied in knowledge workers and artists, as a major indicator of the knowledge economy. The difference between human and creative capital is that the 'creative class' (as Florida labels it) does not necessarily need to have a high educational level in order to create added value. In addition to direct productivity effects produced by knowledge workers, Florida emphasized indirect growth effects from consumption by the creative class in the amenity–rich urban environments in which they live.

6.3 Multilevel models and variables

We use multilevel modeling in our empirical testing, which allows for the simultaneous modeling of the micro- and macro-levels. There are two distinct advantages of multilevel models. First, multilevel models offer a natural way to assess contextuality, or to what extent a link between the macro-level and micro-level exists[33]. The application of multilevel analysis to empirical work on economic geography was induced by the observation that firms that share the same external environment are more alike in their performance than firms that do not share the same external environment. In this fashion, the extent to which variance in firm performance can be attributed to between-firm variance and between-area variance can be assessed (Bullen et al., 1997). Even though it is common in microeconomics to assess the impact of contextual variables on the individual level (see, e.g., Henderson 2003, Audretsch and Dohse 2007), this still neglects the error terms at the contextual level and underestimates the standard errors of the parameters (Raudenbush and Bryk 2002). This can lead to spurious significant effects (Hox 2002).

Second, multilevel analysis allows heterogeneity to be incorporated into the model by varying relationships across contexts. For example, the effect of urbanization externalities may vary across small and large firms or across sectors. Multilevel frameworks are designed to capture this complexity by the inclusion of random coefficients (Snijders and Bosker 1999).

Multilevel models provide a test of the assumptions of 'learning regions' in the sense that contextual effects can be differentiated from compositional effects. Contextual effects occur when group differences are attributable to the effects of group-level variables or properties. When inter-group (or inter-context) differences in an outcome (for example, differences in firm productivity) are attributable to differences in group composition (that is, in the characteristics of the individuals of which the groups are comprised), they result from compositional effects.

The multilevel model is summarized in the following formula (where i represents firms and j regions, with explanatory variable X_{ij} at the firm level and explanatory variable Z_j at the regional level):

$$Y_{ij} = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j + \mu_{0j} + \mu_{1j} X_{ij} + e_{ij} \tag{6.1}$$

The segment $\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j$ in equation 1 contains all of the fixed coefficients; it is the fixed (or deterministic) part of the model. The segment $\mu_{0j} + \mu_{1j} X_{ij} + e_{ij}$ in Equation 6.1 contains all of the random error terms; it is the random (or stochastic) part of the model. The term $X_{ij} Z_j$ is an interaction term that appears in the model because of modeling the varying regression slope β_{1j} of the respondent-level variable X_{ij} with the group level variable Z_j. The difference from a usual regression model is that we assume that each region j has a different intercept coefficient and a different slope coefficient (since the intercept and slope vary across regions, they are often referred to as random coefficients; see Hox 2002).

33 Not taking a multilevel perspective (and instead utilizing a single level analysis) renders one vulnerable to the problems of the ecological and atomistic fallacies (see Hox 2002).

6.4.1 Variables

Starting from the conceptualization of the resource-based view of the firm in section 6.3, we now describe the variables used in our models. For the firm-level data, our paper draws on a survey with data concerning 2,009 firms in manufacturing and business services. The survey was conducted in 2005 (see appendix 6.1).

Firm-level variables

On the firm level, our performance indicator is the level of labor productivity[34], measured as the added value per employee. The firm added value is determined as the yearly turnover minus purchases (all intermediate goods and services needed in the production process of the firm). The added value includes the firm's profits, taxes, subsidy and wages. Labor productivity is distilled by dividing the added value by the number of employees (in full-time equivalents, defined as jobs of more than 12 hours a week).

A firm's absorptive capacity depends to a large extent on its existing (prior) stock of knowledge, much of which is embedded in its products, processes and people (Cohen and Levinthal 1989). Often it is suggested that basic R&D capabilities constitute a firm's absorptive capacity (Cassiman and Veugelers 2006). For business services firms (which conduct less R&D, but rely heavily on professional knowledge), this is often indicated by the number of knowledge-intensive jobs, like consultancy (Illeris 1996). We measure a firm's total number of knowledge-intensive occupations as a percentage of the total number of jobs. This includes, for manufacturing firms, the number of occupations in research and development and, for business services, the number of occupations in consulting (marketing- and design-related). Other jobs within the firm concern management, facilitating services, purchasing, logistics or production.

We account for the use of ICT and face-to-face contact by selecting these transfer mechanisms from a survey question on the types of transfer mechanisms used in inter-firm relationships. They are expressed as the sum of all types of transfer mechanisms (personal, written, telephone, e-mail, e-commerce and other types of contact). These variables are direct measurements of how a firm handles its inter-firm relationships by different communication channels.

We take firm size into account by the firm's turnover. Our hypothesis is that firm size is positively related to productivity due to economies of scale. Age is measured by the number of years since the firm entered business (year of foundation of the establishment). As indicated, firms can suffer from lock-in, which is more of a risk for old firms since successful firms are better equipped to serve market niches and become productive with just a few employees. Besides the primary effect

34 Several authors over the years have claimed that increasing returns to density, for instance in the intensity of knowledge sources, play a crucial role for explaining differences in productivity over space (Ciccone and Hall 1996, Moomaw 1981, Lucas 1993, Kim 1997). Firms cluster and profit from densities to economize on the transport of goods, people, and ideas. These three motives for economic agglomeration are also known as availability of intermediate/final goods, labor market pooling, and knowledge spillovers, respectively (Combes and Duranton 2006). Especially, cities and agglomerations are related to these performance-enhancing forces. A number of aspects bounded to cities argue in favor of their positive relationship with economic performance. Particularly, knowledge spillovers (or externalities) form a mechanism in firm-external economies and are considered as a key element in growth models (Henderson 2007, Koo 2005). The same reasoning holds for productivity growth (Henderson 2007). We will discuss later why we do not present productivity growth models.

Table 6.1 Variables in the analysis

	Variable	Abbreviation	Description	Min	Max	Mean	St.dev.
Firm level	Age	*AGE*	Years ago the establishment was founded, interval 1=1, 2=2, 3=3, 4=4, 5=5, 6=6-10, 7>10	0.00	1.95	1.77	0.33
		AGE^2	Squared-term of *AGE*	0.00	3.79	3.24	0.89
	Size	*SIZE*	Yearly establishment's turnover	-9.21	20.91	13.83	1.87
	Industry dummies	*LIM*	Dummy Labor-intensive manuf.	0.00	1.00	0.12	0.33
		CIM	Dummy Capital-intensive manuf.	0.00	1.00	0.07	0.25
		KIM	Dummy Knowledge-intensive manuf.	0.00	1.00	0.12	0.33
		BS	Business Services (BS).	0.00	1.00	0.69	0.46
	Product specifics	*PROD.SPEC*	Amount of products that are 'custom-made or specifically designed' (2) and 'co-produced' (3) in relation to their customers in the total number of products and services.	-9.21	5.00	3.57	2.77
	Knowledge-intensive occupations	*KI.OC*	Percentage of jobs in research or consulting activities relative to total number of jobs in the establishment	-9.21	4.61	-0.66	5.52
	Face-to-face contacts	*F2F*	Percentage of personal physical contacts relative to total communication of business relations	-6.91	4.61	3.01	2.28
	Inform. and comm. technology	*ICT*	Percentage of contacts by ICT relative to total communication forms of business relations	-6.91	4.61	3.23	2.08
Regional level	Regional growth	*GROWTH*	Employment growth in total number of jobs in the region	0.85	1.28	1.03	0.08
	Regional density	*DENSITY*	Number of jobs per square kilometer in the region	3.01	8.03	5.29	1.08
	Specialization LIM	*SPEC LIM*	Number of jobs in LIM per total number of jobs in the region	-9.21	-1.67	-3.69	1.07
	Specialization CIM	*SPEC CIM*	Number of jobs in CIM per total number of jobs in the region	-9.21	-1.09	-4.02	1.37
	Specialization KIM	*SPEC KIM*	Number of jobs in KIM per total number of jobs in the region	-9.21	-1.58	-3.74	1.38
	Specialization BS	*SPEC BS*	Number of jobs in BS per total number of jobs in the region	-2.97	-0.63	-1.57	0.39
	Regional diversity	*Diversity*	Gini coefficient	-0.81	0.16	-0.70	0.11
	'Knowledge workers'	*'KW'*	Factor loading on Educational level, ICT-use and communicative and creative abilities	-1.80	2.42	0.50	1.02

Variable	Abbreviation	Description	Min	Max	Mean	St.dev.
‘Research and Development’	*‘R&D’*	Factor loading on R&D and high- and medium-tech presence	-1.53	3.95	0.06	1.08
‘Innovation’	*‘INN’*	Factor loadings on Technological and Non-technological Innovation	-2.11	1.99	0.14	1.02
Higher Education	*HE*	Dummy for presence higher vocational education institute	0.00	1.00	0.15	0.36
University	*UNI*	Dummy for presence of a university	0.00	1.00	0.07	0.26

of age, we additionally suppose a nonlinear relationship between productivity and the age of firms. We control for this effect by including an age-squared variable. Age is assumed to positively affect productivity, unless firms are of 'real age'.

We control for industry-specific characteristics by including industry fixed effects based on four broad industries, built up by two digit NACE-codes (appendix 6.2). We include differences in labor-, capital-, and knowledge-industrial intensities and in business services (Van Oort 2004). These industry fixed effects control for the fact that there are differences in productivity between industries.

We also account for the fact that products and services are distinct from one another in being (1) 'standard', (2) 'custom-made or specifically designed' or even (3) 'co-produced' (including risk-sharing) in relation to their customers. One could argue that the more knowledge-intensive the customization is (we assume that type 3 is the most knowledge-intensive, followed by type 2, then type 1), the more proximity matters. We include in our models the amount of products and services specifically customized or co-produced (the sum of types 2 and 3) in relation to the total number of products and services as a proxy for the variety in knowledge intensity of the customers' relationships with a firm.

Regional-level variables
All spatial variables (reflecting opportunities for spatial externalities) draw upon a database that includes all establishments in the Netherlands involved in all types of economic activities (LISA database). This database is aggregated to a regional level (128 municipalities, corresponding to cities). Localization economies are measured by specialization measures for four types of economic sectors: labor-, capital- and knowledge-intensive manufacturing and business services. Urbanization economies are measured by a density indicator: the number of total jobs per square kilometer. Jacobs' externalities are measured by a diversity measure (Gini coefficient) that takes into account the employment distribution across all (2-digit NACE sectors; 58 in total) industries in the region. Regions can vary according to whether employment is strongly concentrated in one industry or distributed equally among industries (relative to the national distribution). We control for regional growth in general as this implies increasing market size, hence creating general opportunities for business (Audretsch et al. 2006).

Specific knowledge-related externalities are included by eight indicators covering the latent concept of the knowledge economy:

4. Educational level. A highly educated workforce has more opportunities to absorb and use information.
5. Communicative skills. These capabilities complement the educational aspects due to the ability to persuade and convince others (and therefore select information).
6. Creative capital. Recently, creativity has been indicated as a driver for innovation and economic growth, besides educational skills as such, with an added value on its own.
7. Information and communication technologies (ICT). As general purpose technology, ICT can be related to economic performance, especially functioning as an optimal vehicle of knowledge transfer when information is codified.
8. Research and development (R&D). Often indicated as the main knowledge source for economic renewal.

9. High- and medium-tech economic activities. This indicate the representation of technology firms and technology-driven international networks and exports.
10. Technological innovation. Representing the actual innovative output of firms.
11. Non-technological innovation. Representing managerial and organizational renewal and more services-related renewals.
12. Additionally, dummies for the presence of a university or higher vocational educational institute are included.

As some of these variables are highly correlated, direct inclusion of the indicators would thus lead to multicollinearity and hence an increase of the estimated variances of the estimators of their coefficients, which might lead one to drop some of the variables incorrectly from the productivity model.[35] Therefore, we include three latent variables in the model rather than the eight separate indicators (see also Raspe and Van Oort 2006). The latent variables are related to their observable indicators via a (principal component) measurement model. We distinguish the following latent variables (appendix 6.3 shows the factor scores and principal components): [1] 'Knowledge workers' with indicators: ICT sensitivity, educational level, creative class, and communicative skills, [2] 'R&D' with indicators: the density of high- and medium-tech firms and the share of R&D employees and [3] 'Innovativeness' with indicators: technical and non-technical innovations. Table 6.1 summarizes all variables and gives a brief description of how they are measured, including their descriptive statistics.

6.5 Empirical results

6.5.1 Econometric estimates

This section describes the empirical models in several steps according to different model specifications. First we introduce the null model, an intercept-only model, to decompose the variance and determine the intraclass correlation. These types of models do not explain any variance; they only decompose the variance into two independent components: the variance of the lowest level errors and the variance of the highest level errors. The intraclass correlation is equal to the estimated proportion of the higher level variance compared to the estimated total variance. Second, we add firm-specific variables to the model (model 1). Third we add in all kinds of regional variables (models 2 - 5). Table 6.2 shows the outcomes of the different models.

The null model gives an indication of the part of the variation that can be assigned to place-contextual variables: 2.3% of a firm's productivity can be related to its location (and more than 97% to matters of internal organization). Our first conclusion therefore is that (though, of course, internal factors are dominant) 'space plays a role'. External economies on the firm level thus do exist and are locally bounded on the spatial scale of urban municipalities. In line with findings by, for instance, Moowah (1981), Kim (1997) and Ciccone and Hall (1996) on the spatial level, the empirical results of the multilevel analyses indicate that the relationship between agglomeration effects and firm performance indeed holds at the firm level. Even in a relatively small country like

35 For example: regions specialized in ICT-intensive activities are usually also characterized by a highly educated labor force. In addition, R&D-intensive regions usually also contain many high- and medium-tech firms.

The Netherlands (with its polycentric urban structure and no real big cities), location matters by providing potential firm-level productivity advantages.

The main internal factor that determines firm productivity is firm size: the larger the firm, the more a firm can profit from scale economies and the higher its productivity. This is in line with the findings of (Jovanovic 1982 and Griliches 1979). Also, the knowledge intensities of the product relationships seem to matter as we find that the more customization, i.e., product differentiation, a firm offers, the more efficiency gains it obtains.

Concerning absorptive capacity indicators, we expected a positive impact of the amount of knowledge-intensive jobs, but we did not find such a correlation. The internal knowledge base in general terms is not convincingly related to productivity. Some robustness checks show that the size-effect - related to the firm's knowledge base - captures part of this absorptive capacity influence[36]. Another finding is that models with no sectoral fixed effect show a positive effect of knowledge-intensive jobs on productivity. A firm's internal knowledge base, often related to its absorptive capacity, thus turns out to be a complex variable that is related to the size of the firm and its industrial characteristics.

Face-to-face interaction, often indicated as a vehicle of tacit knowledge exchange, is also not significant. Face-to-face interaction is not an adequate condition for performance on its own. It might function as the linking pin between regional knowledge sources and firm success, though, a possibility that we will investigate in the next section What we do find is that the use of ICT enhances firm productivity. The more ICT firms use, the higher their productivity. This is in line with Van Ark and Piatkowski (2004).

Concerning the age of firms, we suggested a positive relationship of this indicator with productivity, signifying that firms can learn from their own experience and reduce their costs. On the other hand, we assumed that firm performance tends to decline as the firm evolves over its life cycle (meaning that the age-squared variable is negatively related to productivity). Our expectations were confirmed for the second part of the hypothesis only: age-squared is indeed significant and negatively related to productivity. We do not find a positive significant age effect. Although not (too) highly correlated with the size of firms, age becomes positively significant when the size variable is excluded from the models.

Model 2 specifically adds specialization and diversity on the regional level. These turn out to be insignificant. This means that firm productivity cannot be related to external knowledge sources that have to do with the composition of economic activities external to the firm. When we more specifically define this external knowledge context, in 'knowledge workers', 'R&D' and innovation (model 3), we indeed find a significant and positive impact of being located in an innovative environment. This implies that proximity to innovators is indeed fruitful. Remarkably, our analyses show that a high intensity of external localized research and development does not enhance a firm's productivity. The literature on spillovers often has a strong focus on these technological spillovers. We find that the collective context of the introduction of new products and services to the market,

36 Due to multicollinearity problems, we do not include the number of knowledge-intensive jobs at the same time as size. The number of knowledge-intensive jobs turns out to be significant when size is excluded in the models.

but not the research-related knowledge sources, matters. Finally, the 'knowledge workers' factor is not significantly related to productivity. Model 4 shows that our findings are robust when all variables are simultaneously included.

Finally, model 5 focuses on the three external knowledge variables by including not only the regional variables, but also their spatially weighted variants. For all regional variables, it seems possible that firm benefits exceed the border of the regional unit of analysis (here, municipalities). As a result, spatial autocorrelation might lead to misspecifications of the models. We carried out checks for spatial autocorrelation by checking the significance of spatially weighted versions of the regional variables (linear and quadratic). For each of these variables, the value for the region in which a firm is located (original variable) as well as the average of the values of the neighboring regions (the spatial lag) were included in the models (see Varga 2000, Van Oort 2004 and Knoben 2008 for elaboration and literature review on the topic of spatial lag variables). The lagged regional knowledge variables are not significant, and model specifications including these lags did not improve the models. The latter result indicates that spillovers possibly are not locally bounded, but function on a larger scale. As the outcomes are not significant, we concluded that the phenomenon of firms profiting from their location indeed has a steep distance decay.

6.5.2 Random slopes and interaction effects

Focusing on the effect of localized knowledge externalities, so far we have analyzed whether there is a positive relationship between localized knowledge externalities and productivity within each region. However, this relationship might not be a fixed relationship over all regions ('fixed' meaning that it does not vary between regions). It can be argued that some firms - based on firm-specific characteristics, like size, age or industry - can profit more than others. Where we did not find a relationship between localized knowledge externalities (as in the case of research and development), it might be the case that only some type of firms profit from these externalities (for example, the most knowledge-intensive firms, or the smallest firms).

In this section, we test for cross-level interaction effects between variables measured at different levels of our hierarchically structured data set (see Kreft and de Leeuw (2004) and Hox (2002)). These effects can be tested for all firm-level variables. The first step is the estimation of random coefficient models in which the slope of any of the explanatory variables on the micro level has a significance variance component between the regions. It appears that *AGE*, *SIZE PROD. SPEC* and *ICT* have significant slope variances. This also means that the amount of face-to-face interaction (*F2F*), as we earlier expected, does not function as the link between the region and firm performance. This suggests that some critical (minimum) level of face-to-face interaction is necessary or that a high level of face-to-face interaction only is a necessity in the early stage of trust-based relationships and not in general terms (though we cannot control for such effects). Similarly, we found earlier that the firm's internal knowledge base (*KI.OC*) does not function as a prerequisite for absorbing localized external knowledge sources. We cannot subscribe to the often as stylized facts presented impact of face-to-face interaction and absorptive capacity in our empirical models. This means that these kinds of fundamentals in territorial innovation theories at least require more elaboration.

We now turn to the tests for possible cross-level interactions of the variables that have a slope variance. A first important conclusion, though, is that the covariances between the region's

Table 6.2 Models on firm-level productivity (log transformed variables)

	FIRM-LEVEL PRODUCTIVITY '05						
	Random effect models (Random intercept)						
		Null	Model 1	Model 2	Model 3	Model 4	Model 5
Firm level	Constant	10.627*** (0.084)	3.832*** (0.743)	5.135*** (1.513)	4.128*** (1.091)	5.543*** (1.597)	4.092*** (0.758)
	AGE		1.335 (0.872)	1.356 (0.873)	1.369 (0.873)	1.379 (0.873)	1.379 (0.872)
	AGE^2		-0.554* (0.324)	-0.563* (0.324)	-0.570* (0.324)	-0.570* (0.324)	-0.572* (0.324)
	SIZE		0.415*** (0.034)	0.410*** (0.034)	0.407*** (0.034)	0.406*** (0.034)	0.407*** (0.034)
	PROD.SPEC		0.042** (0.022)	0.044** (0.022)	0.043** (0.022)	0.043** (0.022)	0.043** (0.022)
	KI.OC.		0.001 (0.018)	0.001 (0.018)	0.001 (0.018)	0.001 (0.018)	0.003 (0.018)
	F2F		0.026 (0.027)	0.028 (0.027)	0.027 (0.027)	0.029 (0.027)	0.026 (0.027)
	ICT		0.060** (0.029)	0.057** (0.029)	0.058** (0.029)	0.057** (0.029)	0.059** (0.029)
Regional level	*GROWTH*			-0.394 (1.153)	0.145 (1.125)	-0.169 (1.155)	-
	DENSITY			0.043 (0.106)	0.036 (0.110)	-0.047 (0.122)	-
	SPEC LIM			0.153 (0.130)	-	0.174 (0.140)	-
	SPEC CIM			-0.081 (0.096)	-	-0.110 (0.096)	-
	SPEC KIM			0.089 (0.088)	-	0.054 (0.100)	-
	SPEC BS			0.222 (0.245)	-	0.260 (0.263)	-
	Diversity (Gini)			0.224 (0.273)	-	0.229 (0.275)	-
	'KW'				-0.025 (0.106)	-0.009 (0.138)	-0.042 (0.077)
	'INN'				0.184** (0.095)	0.207** (0.097)	0.205** (0.108)
	'R&D'				0.115 (0.072)	0.087 (0.086)	0.095 (0.079)
	HE				-0.223 (0.248)	-0.169 (0.246)	-
	UNI				-0.223 (0.248)	-0.140 (0.253)	-
Reg-plus level	*'KW' lag*						-1.641* (0.885)
	'INN' lag						-0.149 (0.612)
	'R&D' lag						-0.920 (0.886)
	Ind. fixed effects	No	Yes	Yes	Yes	Yes	Yes

FIRM-LEVEL PRODUCTIVITY '05						
Random effect models (Random intercept)						
	Null	Model 1	Model 2	Model 3	Model 4	Model 5
-2*loglikelih.	9870.6	9694.4	9687.2	9685.2	9681.8	9684.2
R-square i	-	7.5%	7.5%	7.5%	7.5%	7.5%
R-square j	-	43.6%	34.1%	44.7%	44.1%	56.4%
Intraclass	2.3%	-	-	-	-	-

Standard deviation between parentheses, ni =2009, nj=128, *** significant at the 0.01 level, ** significant at the 0.05 level, * significant at the 0.10 level.

PROD. SPEC. = Customized products or services, KI.OC = Knowledge-intensive occupations, F2F = Face-to-face contact, ICT=Information and Communication Technology, SPEC LIM = Specialization in Labor-Intensive Manufacturing, SPEC CIM = Specialization in Capital-Intensive Manufacturing, SPEC KIM = Specialization in Knowledge-Intensive Manufacturing, SPEC BS = Specialization in Business Services, 'KW' = Knowledge workers, 'R&D' = Research and Development, 'INN' = Innovation, HE = Higher Education, UNI = University

Robustness checks: Industry, Time, Regional

- In our models, we tested for specifications of industry fixed effects by the distinction between Labor-, Capital- and Knowledge-intensive manufacturing and Business Services. These turned out to be significant. Dummy coefficients are not included in the table.
- The second robustness test was for potential disturbances due to time influences (market conditions or economic climate). Our data allow us to test for cross-sections of the years 2000 and 2005 (and the average productivity in this period). All directions and significance levels of the coefficients in the models are the same for models of 2000, 2005, and the average in this period. We choose to show the 2005 models.
- We also tested for regional fixed effects: whether a location in one of the eight Daily Urban Systems has an extra contribution to productivity. These models, including specifications of this higher spatial level (agglomeration), were insignificant and showed no model improvements.
- Spatial lag models: We carried out checks for spatial autocorrelation by checking the significance of spatially weighted versions of the regional variables (linear and quadratic).

Variance explained

Knowing that there is a contextual effect on firm productivity and that firm internal characteristics are dominant, the question remains of 'how much variance is explained?'. In multilevel regression analysis, the issue of modeled or explained variance as a test statistic is complex. It can be estimated by examining the residual error variances in a sequence of models where the null model is the baseline model. This must be issued level-by-level (Hox 2002). For our models, we see that the proportion of variance explained at the firm level is 7.5%. Model 2a shows that although no level 2 variables are added, 41% of the municipal-level variance is explained by firm internal characteristics. If the proportions of, for example, size and sector are not exactly the same in all regions, the regions differ in their average firm size or sector, and this variation can explain some of the regional level variance in average productivity between regions. Model 3 raises the R-squared by 4% (to 45,5%) by adding the regional knowledge factors.

intercepts and slopes for age, size and product specifications are negative. This negative covariance suggests that a higher intercept is associated with a lower slope. In other words: larger, older, and more diversified firms are less productive in some regions, or their counterparts, smaller, younger and more standardized firms, are more productive in some regions. The question now is whether localized knowledge externalities contribute to this.

Table 6.3 shows the results of the random coefficient models where we allowed for the possibility that the coefficients of *AGE* (model 6), *SIZE* (model 7), *PROD.SPEC* (model 8) and *ICT* (model 9) can vary from region to region and regions therefore can have different slopes. In these models, we take the cross-level interaction effects into account. We find that in particular, the interaction effects between *SIZE* and a firm's external innovation intensity (*INN*) are significant. This means that in the relationship between localized knowledge externalities and productivity, firm size plays an important role. As this interaction variable is negative, this suggests that smaller firms especially profit from spatially bounded innovation externalities, and not larger firms. Smaller firms, which are less able to perform research and development activities or invest in knowledge sources themselves,

Table 6.3 Models on firm-level productivity (log transformed variables)

FIRM-LEVEL PRODUCTIVITY '05

	Random effect models (Random intercept and slope)	Model 6 *AGE* random coeff	Model 7 *SIZE* random coeff	Model 8 *PROD.S* random coeff	Model 9 *ICT* random coeff
Firm level	Constant	4.828*** (1.268)	3.699*** (1.367)	4.770*** (1.016)	4.416*** (1.045)
	AGE	1.175 (1.056)	1.540* (0.858)	1.362 (0.860)	1.459* (0.859)
	AGE^2	-0.537 (0.351)	-0.621** (0.318)	-0.573* (0.319)	-0.610* (0.319)
	SIZE	0.411*** (0.034)	0.522*** (0.079)	0.396*** (0.034)	0.415*** (0.034)
	PROD.SPEC	0.043** (0.022)	0.032 (0.022)	0.054 (0.044)	0.040* (0.022)
	KI.OC.	0.001 (0.018)	0.001 (0.017)	0.004 (0.017)	-0.006 (0.018)
	F2F	0.029 (0.027)	0.031 (0.026)	0.033 (0.027)	0.009 (0.027)
	ICT	0.059** (0.029)	0.062** (0.029)	0.054* (0.030)	0.088 (0.073)
Regional level	*GROWTH*	0.235 (1.098)	0.552 (1.067)	0.355 (1.075)	0.474 (1.097)
	DENSITY	-0.034 (0.096)	-0.137 (0.097)	-0.032 (0.094)	-0.036 (0.097)
	Diversity (Gini)	0.235 (0.277)	0.285 (0.288)	0.246 (0.221)	0.217 (0.226)
	'KW'	-0.186 (0.503)	0.395 (0.797)	-0.148 (0.107)	0.095 (0.196)
	'INN'	-0.595 (0.586)	2.976*** (0.0871)	0.454*** (0.116)	0.040 (0.229)
	'R&D'	0.293 (0.506)	1.033 (0.767)	0.138 (0.089)	-0.132 (0.222)
	AGE'KW'*	0.070 (0.276)	-	-	-
	AGE'INN'*	0.451 (0.325)	-	-	-
	AGE'R&D'*	-0.106 (0.281)	-	-	-
	SIZE'KW'*	-	-0.029 (0.055)	-	-
	SIZE'INN'*	-	-0.201*** (0.061)	-	-
	SIZE'R&D'*	-	-0.070 (0.053)	-	-
	PROD.SPEC'KW'*	-	-	0.025 (0.016)	-
	*PROD.SPEC *'INN'*	-	-	-0.079*** (0.025)	-

FIRM-LEVEL PRODUCTIVITY '05				
Random effect models (Random intercept and slope)				
	Model 6 *AGE* random coeff	Model 7 *SIZE* random coeff	Model 8 *PROD.S* random coeff	Model 9 *ICT* random coeff
*PROD.SPEC *'R&D'*	-	-	-0.014 (0.020)	-
ICT'KW'*	-	-	-	-0.045 (0.049)
ICT'INN'*	-	-	-	0.048 (0.060)
ICT'R&D'*	-	-	-	0.070 (0.059)
Industry fixed effects	Yes	Yes	Yes	Yes
-2*loglikelih.	9675.9	9632.1	9644.2	9655.6

St.dev. betw. parentheses, *** sig. at the 0.01 level, ** sig. at the 0.05 level, * sig. at the 0.10 level.

profit more from externalities than larger firms that often internalize these sources. This is in line with research by Acs et al. (2004).

Model 8 shows that product specifications related to knowledge intensities in customization also have a negative interaction coefficient, meaning that firms that are more standardized in their products and services profit more from innovative spatial contexts than firms that are more customized (diversified) in their firm-buyer relationships. This is remarkable. Possibly the customization of firm-buyer relationships requires many innovative forces and renewal capabilities that mainly involve internal processes, while more standardized relationships can profit from external innovations.

6.6 Conclusions

One of the main criticisms of concepts like 'learning regions' is that the role of the firm is conceptually and empirically underdeveloped. By arguing that interactions between firms and regions are an intrinsically multilevel issue, we tried to contribute to a better understanding of the knowledge conditions that shape economic performance on the level of the firm. This means that regional knowledge circumstances (might) impact firm-level performance simultaneously with firm-specific characteristics. We also allow for the possibility that relationships on the level of the firm (might) vary interactively with these regional knowledge circumstances. Contextual effects may not be the same for all types of firms and mutually depend on certain firm-specific characteristics. After conceptualizing the extension of a resource- or knowledge-based view of the firm with externalities stemming from the spatial economics literature, we tested some of these firm-regional interactions by estimating multilevel models.

One of our main findings is that 'space' plays an independent role, but its impact is minor compared to firm internal factors. Only 2.2% of the firm's productivity can be related to its location (and more than 97% to matters of internal organization). Thus, even in a relatively small country like

The Netherlands, location matters by providing potential firm-level productivity advantages. We find indications that within a region, certain knowledge circumstances indeed enhance firm performance. In particular, being located in an innovative environment was found to be fruitful. The literature on knowledge transfers often has a strong focus on technological spillovers (like research and development), but we conclude that the stimulating effect of sharing a regionalized context with successful innovators should be more incorporated. A broad perspective on the spatial heterogeneity of knowledge gives this insight.

Besides finding that firm characteristics enhance productivity as such (for instance, we found, in line with the literature, that firm size, ICT usage and product specification result in higher productivity), we also found that contextual effects are not the same for all types of firms. Larger and/or older firms and those offering more knowledge-intensive product specifications (related to customization) are less productive in some regions, while their opposites, smaller, younger and more standardized firms, are more productive in some regions (since they appear to have significant slopes in our multilevel models). The most robust finding concerning knowledge-related conditions is that the interaction effect between a firm's size (*SIZE*) and its external innovation intensity (*INN*) is significant. This means that in the relationship between localized knowledge externalities and productivity, firm size plays an important role. Especially, smaller firms profit from spatially bounded innovation externalities, and not larger firms. Smaller firms, which are less able to perform research and development activities or invest in knowledge sources themselves, profit more from externalities than larger firms that often internalize these sources.

We conclude that it is important to incorporate firm-specific characteristics into concepts like 'learning regions'. Simultaneously and mutually modeling firm and regional characteristics is fruitful for a better understanding of the spatial knowledge and learning conditions that shape economic development on the level of the firm.

Appendix 6.1 Survey

A random stratified sample, taking firm size, sector and region into account, was taken from the LISA database (an employment register of all Dutch economic establishments, see Van Oort et al. (2007)). For this research, we included only firms in manufacturing and business services with more than one employee. The response rate was approximately 7% (representative of the stratification by region, size and sector). Table 6.4 shows the population, survey and response rates (see Van Oort et al 2006 and Ritsema Van Eck et al. 2006 for more elaboration representativity of the survey).

Table 6.4 Population, Survey and Response

	# Municipalities	population	survey	response	response %
Region Amsterdam	16	17.141	5.980	399	6.7%
Region Rotterdam	28	9.710	4.818	357	7.4%
Region Groningen	12	2.720	2.128	167	7.8%
Region Eindhoven	16	6.287	3.763	289	7.7%
Region Apeldoorn/Dev/Zutph	9	3.204	2.217	162	7.3%
Region Arnhem-Nijmegen	23	5.324	3.259	271	8.3%
Region The Hague	11*	4.921	3.117	185	5.9%
Region Utrecht	13	5.486	3.355	179	5.3%
TOTAL	128	54.792	28.637	2.009	7.0%

* Overlap with region Rotterdam

Appendix 6.2 NACE codes

Table 6.5 Sector and NACE-codes

SECTORS (based on 2 digit NACE-codes)
Labor-intensive manufacturing 17, 18, 19, 20, 28, 36, 37
Capital-intensive manufacturing 15, 16, 21, 25, 26
Knowledge-intensive manufacturing 23, 24, 27, 29, 30, 31, 32, 33, 34, 35
Knowledge services 22, 64, 65, 66, 67, 70, 71, 72, 73, 74

Appendix 6.3 Factor analysis

Table 6.6 shows the factor scores for these principal components. Bold values mark the loadings of the indicators that are taken together in the three factors.

Table 6.6 Factor scores of principal components (eight indicators of the knowledge economy).

	Factor 1	**Factor 2**	**Factor 3**
Indicators:	'Knowledge workers'	'Innovation'	'R&D'
ICT sensitivity	**0.753**	0.365	0.268
Education level	**0.949**	0.164	0.044
Creative economy	**0.516**	0.024	-0.198
Communicative skills	**0.927**	0.040	-0.069
High-tech and medium-tech	-0.175	0.146	**0.840**
Research and Development	0.080	0.129	**0.836**
Innovation (technological)	0.130	**0.878**	0.246
Innovation (non-technological)	0.147	**0.914**	0.054

Source: Raspe and Van Oort (2006)

Appendix 6.4 Correlations

Table 6.7 Correlation matrix of firm independent variables

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**
1 SIZE	1.00						
2.AGE	0.18	1.00					
3.AGE^2	0.20	0.98	1.00				
4.KI.OC.	0.00	-0.06	-0.07	1.00			
5.F2F	-0.05	0.00	0.00	0.04	1.00		
6.ICT	0.03	-0.02	-0.01	0.05	0.08	1.00	
7.PROD.SPEC	0.11	0.01	0.00	0.11	0.08	0.12	1.00

Table 6.8 Correlation matrix of regional independent variables

	1.	**2.**	**3.**	**4.**	**5.**	**6.**	**7.**	**8.**	**9.**	**10.**	**11.**	**12.**
1.'KW'	1.00											
2.'INN'	0.19	1.00										
3.'R&D'	-0.16	-0.40	1.00									
4.Gini	0.44	0.45	-0.56	1.00								
5.SPEC.LIM	-0.62	-0.21	0.32	-0.36	1.00							
6.SPEC.CIM	-0.52	-0.16	0.26	-0.36	0.60	1.00						
7.SPEC.KIM	-0.29	-0.14	0.55	-0.32	0.47	0.39	1.00					
8.SPEC.BS	0.70	0.29	-0.30	0.45	-0.52	-0.42	-0.25	1.00				
9.DENSITY	0.44	0.22	-0.33	0.47	-0.35	-0.29	-0.17	0.36	1.00			
10.GROWTH	-0.25	-0.22	0.13	-0.28	0.08	0.17	0.28	-0.05	-0.17	1.00		
11.HE	0.17	-0.21	-0.07	-0.10	-0.11	-0.02	-0.13	0.12	0.44	-0.15	1.00	
12.UNI	0.24	-0.37	-0.01	-0.01	-0.06	-0.03	-0.12	0.08	0.36	-0.07	0.68	1.00

7 Growth of new firms and spatially bounded knowledge externalities[37]

Abstract
If localized knowledge spillovers are important, new firms will tend to locate in proximity of one another, as well as other knowledge sources, in order to capitalize on external knowledge stocks. Although theories that emphasize knowledge spillovers thus present the urban and regional character of a firm's proximity to knowledge sources as a stylized fact, the microfoundations of economic growth in agglomerations are among the most anticipated issues in urban economic research. In this paper, we define knowledge intensive environments along several dimensions, and analyze new firms' survival and growth at the individual level. We apply multilevel regression to avoid potential estimation biases, and use firm-level data for newly established manufacturing and business services firms over the period of 2001-2006 in the Netherlands. We find that the urban knowledge context significantly relates to firm-level employment growth, but that this is conditioned by heterogeneous features of the firm population and knowledge externalities, including (a) industries - more in services than in manufacturing; (b) types of knowledge context -more positively related to (non-technical) innovation than to (technologically) R&D related variables; and (c) types of post entry process - different for survival and growth. We also find significant interaction effects between the growth of R&D-specialized firms with university presence.

7.1 Introduction

Substantial work on the role of knowledge in modern growth theory (Romer 1986, Lucas 1988) puts forth opinion that 'knowledge' and its accumulation are crucial factors for generating sustained economic growth in Western economies (Henderson 2007, Koo 2005). Knowledge spillovers form a mechanism through which firms can benefit from the research findings or knowledge of firms working along similar lines (Sena 2004). Recently, various researchers have put forward entrepreneurship as an additional component of 'new growth theory', whereby firms exploit the opportunities provided by knowledge and ideas that are not fully commercialized by incumbent firms (Acs et al. 2004, Audretsch et al. 2006). According to these researchers, the growth of new firms is the missing link between investments in knowledge and economic growth (Audretsch and Lehman 2005b).

Aside from researchers in growth and entrepreneurship economics, the phenomenon of knowledge spillovers brings together the fields of industrial organization, geography and regional science. These fields stress the unsoundness of assuming that spillovers are automatic and costless, and that important restraints on the magnitude and mechanisms of knowledge transfers should be incorporated (Acs and Plummer 2005, Grosmann and Helpman 1991). The geographical and

37 Raspe, O. and F.G. van Oort. Growth of new firms and spatially bounded knowledge externalities, manuscript accepted for publication in The Annals of Regional Science.

regional economics literatures on knowledge spillovers especially provide evidence that knowledge does not diffuse instantaneously across production locations (Döring and Schnellenbach 2006). In this literature, there is a tradition of analyzing the local advantages of proximity or agglomeration and questioning whether regional economic growth is higher in regions where more organizations or knowledge are concentrated (Glaeser et al. 2002, Feldman and Audretsch 1999).

The central argument in this literature is that if knowledge spillovers are important for growth, a firm's location influences its behavior (e.g., location decisions) and performance. In particular, when knowledge is not easily exchanged over longer distances and spills over locally, firms tend to locate proximally in order to capitalize on the knowledge stock of neighboring firms (Koo 2005). Remarkably, while the empirical evidence on linkages between agglomerations and growth focus on regional and local analyses, the relationship should actually and most profoundly hold at the micro or firm level. But, in fact, very little is known about locational impacts on entrepreneurship and firm performance because of limitations in both the conceptualization of linkages between space and firms and data availability (Audretsch et al. 2006). Although several insightful firm-level studies that include the role of the region have been conducted in recent years (e.g., Sternberg and Arndt 2001, Fritsch 2004, Knoben 2008), such studies remain scarce. And these studies often focus on the innovative performance of firms and not on productivity or employment growth (see Audretsch and Dohse 2007 for an exception). Generally speaking, studies on entrepreneurship and industrial dynamics pay too little attention to the role of location (Scott 1995, Parker 2005), and in geography the firm as the research unit is underdeveloped (Maskell 2001, Taylor and Asheim 2002, Harrison et al. 1996). In line with Malberg et al. (2000), and more recently Beugelsdijk (2007), we apply a multilevel modeling approach, analyzing the impact of (types of) agglomerated knowledge on the performance of newly established firms. We use a modeling framework that values individual- and contextual-level elements simultaneously. This framework is applied to a dataset of new manufacturing and business services firms in the Netherlands in 2000-2001, with information on survival and growth trajectories until 2006.

The paper is organized as follows. The next section deals with new firm and post-entry growth, relating to external knowledge sources. Section 7.3 defines the spatially bounded externalities that we will use in our analysis. Section 7.4 (econometric model, variables, and research framework) brings these contextual (regional) knowledge variables together with firm-level characteristics in econometric estimations of new firm growth. Section 7.5 provides the empirical results. In the last section, we conclude by discussing the magnitude of the spatial effect and the impacts of external knowledge factors.

7.2 New firms and external knowledge sources

Recently, entrepreneurship, or the formation of new firms, has garnered substantial attention in the knowledge spillover and economic growth literatures. Acs and Plummer (2005), for instance, argue that new firms matter more than incumbent firms in allowing knowledge spillovers to contribute to economic growth. During the last decade, these types of propositions were especially elaborated in The Knowledge Spillover Theory of Entrepreneurship (Acs et al. 2004, Audretsch et al. 2006). This theory suggests that, ceteris paribus, entrepreneurial activity will tend to be larger in contexts where knowledge endowments are relatively high, as new firms will begin using uncommercialized knowledge spilled over from other firms and universities. As the incomplete knowledge generated in an incumbent organization generates an entrepreneurial opportunity, entrepreneurial activity provides, in turn, the conduit facilitating the spillover and commercialization of that knowledge. The entrepreneurial opportunity, in this theory, is no longer 'just' exogenous and constant (Audretsch and Keilbach 2007).

Entrepreneurship's spillover potential has an important spatial component. Some of the literature on entrepreneurship suggests that entrepreneurial activity (in start-up or entry rates) varies across geographic space (Santarelli and Vivarelli 2007). Audretsch and Lehman (2005a) and Audretsch and Keilbach (2007) find that the number of new firms located close to external knowledge sources (like a university or incumbent firms) is positively affected by the knowledge capacity of the region, with higher knowledge contexts found to generate more entrepreneurial opportunities. These findings constitute the foundation of the proposition that entrepreneurial opportunities will be systematically larger in contexts characterized by more knowledge. By contrast, entrepreneurial opportunities will be systematically lower in contexts characterized by smaller knowledge endowments.

The potential of knowledge externalities for new firms is considered important not only for start-up rates and new firm formation, but also for processes subsequent to entry. One of the important findings of Glaeser et al. (1992) and Feldman and Audretsch (1999) is that economic performance is improved through knowledge spillovers. Questioning whether knowledge externalities bestow new entrepreneurial start-ups with any competitive advantage, Geroski (1995) argues that we can expect new firms' growth and survival prospects to depend on their ability to learn from their environment, and to link changes in their strategic choices to the changing configuration of that environment. This is what Audretsch et al. (2006) find for new firms: opportunities for entrepreneurship, and therefore for knowledge-based start-ups, are superior when they are able to access knowledge spillovers through geographic proximity to knowledge sources, such as universities. Underlying arguments here are that a new firm wanting to generate its own knowledge capital will be limited by scale and time. A new firm that uses external knowledge and ideas can leverage its own knowledge capital by standing on the shoulders of giants.

Other arguments besides the positive impact of knowledge externalities arise for the survival and growth of new firms. The 'geography of opportunity' literature indicates that organizations also compete with one another for vital (knowledge) resources (Sorenson and Audia 2000). Since organizations compete more intensely within local population boundaries, their location can also be a growth constraint (for example, in acquiring specific knowledge and human capital). Stuart and Sorsenson (2003) state that factors promoting new venture formation differ from those that enhance the post-entry performance of early stage companies. New ventures in geographically crowded areas, though benefiting from proximity to knowledge externalities, suffer from the competition that goes along with a heavy concentration of nearby competitors (both incumbent and other new firms). In short, negative externalities can also arise from intense competition among spatially proximate firms. These negative externalities can be rationally taken into account by new firms, considering that although higher failure rates may exist, those firms that do survive in these regions receive higher returns than their counterparts located in remote and less knowledge-intense areas (Sorenson and Audia 2000). This is in line with an empirical study by Audretsch and Mata

(1995) on industry levels, which finds that new firms that do survive the first few years after entry actually have a greater subsequent likelihood of surviving in highly innovative industries.

To summarize, theory on knowledge spillovers and entrepreneurship argues that richer knowledge contexts will generate more entrepreneurial activity (for both new firm formation and post-entry processes) than those contexts poorer in knowledge. The question that arises is whether new firms, triggered by and using external knowledge inputs, will exhibit superior performance when located in knowledge rich contexts. Here, both the 'increasing returns to agglomerated knowledge resources' argument (including proximity to external tacit knowledge sources through face-to-face interaction) and the competition argument come together. One of the empirical peculiarities of determining spatial impacts of knowledge externalities on firms is that the dependent variable in econometric analysis is often a spatial measure of entrepreneurial activity, for instance start-up rates defined as the number of start-ups divided by the population at a certain regional level. Very little is known, then, about the locational impact on entrepreneurship and firm performance because of limitations in both the conceptualization of linkages between space and firms, as well as data availability. By focusing on 'the firm", we place processes subsequent to entry at the center of our analysis: in particular, the survival and post-entry growth of new firms. An obvious advantage of focusing on new firms is that they are less constrained by previous decisions, such as past capital installments, which may influence how these firms value the marginal worker and whether they create new employment (Rosenthal and Strange, 2003). In this fashion, we avoid endogeneity problems that are often present in analyses of 'old' establishments.

7.3 Spatially bounded knowledge externalities

In defining localized knowledge externalities that impact firm survival and growth, it can be argued that the most profound knowledge sources at the regional level are technical and production oriented factors like research and development (R&D) within companies, research labs, or universities (as shown by Black 2004, amongst others) or the intensity of high- and medium tech firms (see Cortright and Mayer 2001). But aside from these technological drivers, 'softer' human capital related elements are also important. Lucas (1988) and Mathur (1999), for instance, argue that a well-educated workforce has ample opportunities to absorb and use information. Therefore, characteristics like (higher) education are often related to economic growth. Thus, being located near a higher education institute can enhance entrepreneurial potential (Florax and Folmer 1992, Varga 2000).

In addition to technological and human capital spillover potential, (new) firms can also profit from 'being near' to 'successful innovators': firms that were successful in introducing a new product or service to the market. Innovation differs from investments in R&D, as R&D is not always guaranteed successful renewal due to uncertainties and trial and error processes. Especially for new firms unable to invest in R&D on their own, it can be fruitful to have alliances (formal and informal) with those that have experienced concrete renewal (mostly incumbents). Innovation can be distinguished into technical and non-technical innovations. While technical innovations relate to new products (for service companies: new services) and production processes, non-technical innovations concern renewals in management, marketing, and organization. Both aspects are important in knowledge-based economies (Raspe and Van Oort 2006).

Aside from specific knowledge-related externalities like R&D, high-tech firms, and human capital factors, the literature also indicates an effect of more common regional economic conditions. Bosma et al. (2006) summarize these as demand and supply factors for entrepreneurship (e.g., population growth, income, wages, economic output, industry mix, size structure of local industry, unemployment, composition of the population and labor force, demographic characteristics, financial availabilities, and cultural or policy environmental determinants. Some of these variables should be controlled for while they are generally related to entrepreneurship. For example, a positive regional growth rate implies increasing market size, which creates general opportunities for businesses (Audretsch et al. 2006). Unemployment also often acts as a promoter of starting a new business (Devereux et al. 2007). However, this relationship is ambiguous, as it is also argued that a high unemployment rate implies lower opportunities stemming from lower average individual capabilities. The density of economic activity profiles urbanization economies: external economies available to all local firms, irrespective of sector, and arising from urban size and density. This more general agglomeration effect is assumed to have a positive effect on economic growth, especially for service firms. Manufacturing firms generally profit from more (own-sector) specialized clustering (Van Oort 2004).

Although no consensus has been reached in the literature on the exact spatial range that can be attributed to knowledge spillovers (Döring and Schnellenbach 2006), Lucas (1993) emphasizes that the most natural context for understanding the mechanics of economic growth is in those areas where the compact nature of the geographic unit facilitates communication: cities. Feldman and Audretsch (1999), Glaeser and Maré (2001), and Duranton and Puga (2004) also stress the role of cities and agglomerations. Cities bring together a large number of people, facilitating face-to-face contacts and learning opportunities. In our study, we therefore conceptualize the contextual knowledge economy at the urban level (Dutch municipalities).

7.4 Empirical approach

7.4.1 Multilevel regression modeling

We model firm-level survival and employment growth, taking both firm-specific and contextual independent variables into account simultaneously. To make a distinction between the effects of firm-specific characteristics and external regional characteristics, we use multilevel regression analysis (Raudenbusch and Bryk 2002, Hox 2002, Goldstein 2003, see appendix 7.1 for formal notation).

We choose this modeling technique because it is consistent with our research questions on determining the importance of the urban context for individual new firm growth, and why this context may be important. Multilevel modeling decomposes the variance of firm performance, providing insights into the extent that the urban context matters for firm performance compared to firm characteristics. It also enables us to determine what knowledge-related externalities affect firm performance[38]. Following Burger et al. (2008), applying multilevel analysis to empirical work on economic geography begins with the observation that firms that share the same external

38 Not taking a multilevel perspective (sticking to a single-level analysis) faces the problem of certain research fallacies, namely 'ecological and atomistic fallacies' (see Hox 2002).

environment are more alike in their performance than firms that do not share the same external environment because of the common externalities that they enjoy. In this fashion, we can assess to what extent variance in firm performance can be attributed to between-firm variance and between-area variance. Hence, we are able to assign variability to the appropriate context (Bullen et al. 1997). Even though it is common in micro-economics to assess the impact of contextual variables at the individual level (see e.g., Henderson 2003, Audretsch and Dohse 2007), this still neglects the error terms at the contextual level and underestimates the standard errors of parameters (Raudenbush and Bryk 2002). This, in turn, can lead to spurious significant effects (Hox 2002).

7.4.2 Survival and unconditional employment growth

We analyze post-entry employment growth over the period 2001-2006 for firms that entered business in 2000 and 2001. As we select all new firms in manufacturing and business services that were new entries, and track their growth trajectory, we face the problem of panel attrition through non-survival. This is especially true since we know that new entries are highly correlated with exit rates (Geroski 1995). Firms that do not survive still contribute information to the relationships analyzed. Possible disturbances in the estimates of growth coefficients related to this selection bias occur when characteristics of non-survival are related to firm growth. We control for this selection bias by applying a two-step Heckman procedure: first, a probit estimate of survival from the whole sample (survivors and non-survivors) is made; second, a growth estimate for the selected sample of survivors using the Inverse Mill's ratio (*LAMBDA*) obtained from the first step is used as a correction factor (Heckman 1976). This ratio is a summarizing measure that reflects the effects of all unmeasured characteristics that are related to firm survival, and catches the portion of the non-survivors' effect that is related to growth. This means that the growth models are unconditional on survival. An important condition for this estimation procedure is that, to avoid multicollinearity problems, the selection equation contains at least one variable that is not related to the dependent variable in the substantial (growth) equation. In the section 'variables", we will elaborate on our choice of this instrument (*INSTR*).

In line with previous empirical literature on knowledge spillovers (Brouwer et al. 1993, Audretsch 1995), we use employment as the growth indicator. Employment growth provides an indicator of firm assets, as human resources are among the most important assets for a (new) firm. Innovations that lead to new products and services (more radical innovation) are especially likely to lead to economic growth with new economic activities and new sectors, resulting in employment growth. Contrarily, incremental innovations more often make firms perform more efficiently, leading to greater output per employee and therefore higher productivity (Saviotti and Pyka 2004). This means that changes in employee size are a conservative measure for investigating the instability of growth in comparison with more rapidly changing figures like sales (or productivity) of capital valuation.

7.4.3 Variables

We use the LISA database, which contains all Dutch establishments over the period 2000-2006. We constructed a longitudinal database with individual establishments over the period containing each firm's exact location, number of jobs, and NACE code. From the longitudinal data, we determine the number of years an establishment is in business.

From the industrial organization literature, we know that industry-specific characteristics, such as scale economies, the endowment of innovative capabilities, and technological change and economic growth vary according to the sector in which it occurs. These factors are claimed to have significant impacts on entry, exit, and the likelihood of newborn firms' survival (Santarelli and Vivarelli 2007). For example, in industries characterized by higher minimum efficient scale (MES) levels of output, smaller firms face higher costs that are likely to push them out of the market within a short period after start-up. There are several examples where 'new technology-based firms' in advanced manufacturing and information and communication technology (ICT) services surely play a different role as compared with small-sized start-ups in traditional sectors. As the type of economic activity is important for firm growth, analysts often introduce industry fixed-effects, which capture various technology and knowledge dimensions, such as technological opportunity, appropriability regimes, or the emergence of dominant designs along the technology life cycle (Teece 1986, Breschi et al. 2000).[39]

In addition to industry-fixed effects (2 digit NACE codes), we consider separate models for manufacturing and business services. As agglomeration theory and knowledge spillover theories are originally based on the concentration of manufacturing, we argue that business services firms also profit form agglomerated knowledge sources in cities, as these kinds of activities involve economic activities intended to result in the creation, accumulation, or dissemination of knowledge (Miles et al. 1995). Advanced producer services are characterized by their heavy reliance on professional knowledge, both codified-explicit and tacit-implicit. These services can be considered a primary source of information and external knowledge; they can use their knowledge to produce intermediary services for their clients' production processes, and they are typically supplied to businesses through strong supplier-user interactions (Illeris 1996, Muller and Zenker 2001). Business services therefore tend to cluster in order to profit from agglomerated knowledge externalities (Gordon and McCann 2000). Regarding this issue, our empirical research is exploratory in nature. As some empirical literature on new firms in agglomerations suggests differences between manufacturing firms and business services in terms of their dependence on agglomeration externalities - with services more related to urbanization economies and manufacturing more related to localization economies (Van Oort and Atzema 2004) - we present different models for these two types of firms. Because we focus on knowledge externalities and not on agglomeration externalities in general, we do not a priori formulate different hypotheses for the two models.

We also take firm size into account. As we select new establishments in the years 2000 and 2001, all firms are considered as having the same age. But their initial start-up size differs. Following earlier findings in the organizational ecology and industrial organization literatures (Caroll and Hannan 2000), firm size (and firm age) are considered important individual (firm-level) determinants of growth. It is argued that these factors largely determine a firm's resource-base and competencies.

39 The literature indicates that entry threat might push incumbent firms to innovate more (e.g.. Aghion et al.2008), which, in turn, reduces unexploited knowledge that might spill over into entrepreneurship. We consider testing the relationship between entry rates and innovative performance of incumbent firms as highly relevant, but beyond the scope of our paper (as it focuses on characteristics and strategies of incumbents and not of new firms). The way this 'competition' effect potentially affects the post-entry performance of new firms might be by a bias caused by the industry specific pre-selection of entries. Ideally one wants to test for entry-specific characteristics on type of activity related to innovation and firm strategies. As we do not have this kind of information we incorporate industry fixed effects.

First, larger firms are more likely to have output levels close to their industry minimum efficient scale, and thus are less vulnerable than smaller firms that produce on a smaller scale (Audretsch and Mahmood 1994). Small firms have to overcome cost disadvantages relative to larger firms. Due to 'internal economies of scale", which cause a reduction in per unit costs over the number of units produced, efficiency advantages and therefore growth potential emerge from larger firm sizes. Second, larger firms are usually more diversified than are smaller ones. This reduces their risk of exit since adverse conditions in one market can be offset by better conditions in other markets. Third, in the firm and industry dynamics literature, firm size represents efficiency differences arising from differences in experience, managerial abilities, production technology, and firm organization. (Esteve-Pérez and Manez-Castillejo 2008). It is to be expected that there will be a positive relationship between start-up size and survival, and a negative relationship between start-up size and post-entry growth. SIZE is measured as the number of jobs in the start-up year.

In section 7.2, we argued that R&D can be a knowledge externality. For R&D we measured the sectorally weighted share of R&D employees as an amount of total regional employment. We take the density of high- and medium-tech industries' employment (sectorally defined by the OECD 2003) relative to the total number of jobs as the high and medium tech indicator (*TECH*). Sharing of research organizations is measured by dummies for the presence of a university (*UNIV*) or higher vocational education institute (*HBO*). We use the average educational level of the working population per municipality as an indicator of human capital, which is a crucial feature of the knowledge economy (*EDU*). In this paper, we use firm self-ratings in terms of new products and processes (as expressed by firms in the CIS3-questionnaire for the Netherlands) as our innovation indicator, divided into technological (*INN TECH*) and non-technological (*INN NTECH*) innovation. On the regional level, these are taken into account through the proportion of innovative firms in a municipality.

On the urban level, we measure employment density as the number of jobs per square kilometer (*JOB DENSE*). Unemployment (*UNEMPL*) is the regional number of job seekers amongst the total of inhabitants between 15-65 years. General regional economic growth (*REG GROWTH*) is the growth in total number of jobs over the period 2000-2006 in a region. We only measure the growth of incumbent firms and exclude the regional employment growth generated by new firms. This to avoid possible multicollinearity problems, as regional employment change is (partially) explained by the average change in our dependent variable. These three spatial variables control for generic economic developments and agglomeration economies due to density.

Concerning the instrument (*INSTR*) used in the Heckman estimation procedure for manufacturing firms, we use the average number of bankruptcies per establishment at the regional level (over the period 1994-2006) as an indicator of regional differences in survival probabilities. We argue that being located in a region that has a history in high bankruptcy rates, due to a mix of differences in entrepreneurial conditions, can influence individual survival rates (Raspe and Van Oort 2008). By defining a regional variable in a different time period as the instrument, this relates to new firms' survival chances, but not necessarily to firm growth. In the business services models, we use an indicator of the 'new economy' as an instrument. Following Audretsch and Dohse (2007), a sector dummy for 'Internet, IT Services, Media and Software firms' is used as the instrument, and is hypothesized to have a higher likelihood of failure than for firms belonging to other sectors (this partly reflects the 'death of the dot.coms' phenomenon that could be observed in 2000 and 2001).

Appendix 7.3 shows descriptive statistics for the dependent variable (employment growth) and the independent firm-level and context-level variables (no partial correlations higher than 0.7 exist: Appendix 7.4)[40].

7.5 Results

7.5.1 Survival and growth models for manufacturing and business services firms

Table 7.1 shows the results of our model estimates. Columns 1-3 are the models for new manufacturing firms. Columns 4-6 are the models for new business service firms. Most important for our analyses is the impact of 'the urban context' on firm growth, and the related localized knowledge resources. Table 7.1 therefore starts with the growth models, which contain the unconditional growth specifications following the Heckman procedure (*HECKIT*). The probit models on survival that precede this second step are presented in columns (3) and (6), respectively.

As indicated in section 7.4.1, one of the advantages of multilevel modeling is their decomposition of variance, in our case into the classifications of the micro-level of the firm and that of the region. The ICC test statistic (see appendix 7.1) provides insights into the extent that the region matters for firms' performance as compared to firm characteristics. Columns (1) and (4) show these insights (the null models). One of the main findings is that location does indeed matter for new firm performance: 2.1% of the variance in new manufacturing firms' growth can be assigned to area-effects (for business services this impact is 1.2%). The counterpart to this finding, though, is that the growth performance of new firms is mainly affected by firms' internal characteristics. More than 97% of the total variance is between-firm variance. Although the external environment explains a limited portion of the variation in firm performance, urban context significantly contributes to firm performance after taking into account the enormous between-firm heterogeneity.

Part of this heterogeneity is captured by industry fixed effects and the inclusion of the firm-level variable *SIZE*[41]. Remarkably enough, column (2) shows that, though the region matters, external knowledge sources do not enhance the growth potential of new manufacturing firms. None of the defined external knowledge sources are statistically linked to higher individual growth rates. We do not find any indications that technological externalities like R&D-spillovers or university-related knowledge flows can be linked to better performing manufacturing start-ups. We even find that new manufacturing firms experience lower growth rates in regions characterized by a high intensity of highly qualified (educated) employees. Location in cities that have high human capital (*EDU*) intensity turns out to have a negative impact. One of the explanations for this might be that new manufacturing firms see themselves confronted with incumbent firms in these regions, who absorb the opportunities for new firms to grow. Especially since new firms face difficulties when competing with incumbent firms for 'human capital', they have less opportunity to pay comparable wages.

40 Due to register problems in the province of Friesland and the city of Groningen, firms in these regions are excluded from the analysis.

41 As in our analysis, the focus is on new firms, and there are not many other control variables at the level of the firm. Normally age is an important determinant of firm performance, but all firms are of the same age in our analyses.

New business services firms, on the other hand, seem to profit more from knowledge externalities. Firm growth for new business services is positively influenced by their location in a region that contains agglomerated knowledge resources having to do with renewals in management, marketing, and organization. In other words, successful entrepreneurship related to non-technological innovations is positively related to new firms in the region. A second growth enhancing externality has to do with so-called urbanization economies: economies available to all firms in a region irrespective of the sector they are in, as measured by the concentration of total employment and arising from urban size and density. We find indications that a stronger concentration of jobs in the region has a positive spillover potential for new business services firms. Larger and denser cities especially seem to provide resources that make new business firms outperform their counterparts elsewhere. We find that this density effect has a solitary impact, in addition the fact that dense cities often contain highly educated employment, since we control for this effect on its own (*EDU*). In line with the models for manufacturing, this human capital variable is also negatively related to firm growth.

Before firms can grow, they have to first survive. Models (3) and (6) show the results of the probit regression analysis on survival. Especially for manufacturing firms, we find that larger start-ups have a higher chance of survival than smaller ones. While new firms typically have small start-up sizes, 'economies of scale' still seems to matter in the early years of a business (Audretsch and Dohse 2007).

In terms of the urban contextual factors, we find that new manufacturing firms, as in the growth models, do not experience positive of negative influences on their survival chances. The main exception, however, is the negative impact of density (*JOB DENSE*) on survival chances. Being located in a dense urban region lowers a new firm's chances of surviving. For manufacturing firms, we conclude that it is agglomeration in general and not the agglomeration of knowledge resources that drives the story (in a negative manner, though). Agglomeration seems to function as one of the spatial selection mechanisms, though we do not find this effect at first lowers survival chances. When firms do survive, their growth will be enhanced by the same agglomeration factor.

New business services firms, as we saw, profit from density, but this factor has no impact on their survival rates. Here, agglomerated knowledge sources especially influence firm survival. New business firms located in a region rich in R&D resources experience greater survival rates. Whereas normally the literature assumes that high-tech firms profit from neighboring firms working along similar lines, here we find an effect of cross-fertilization: new service industries profit from their co-location with manufacturing industries. On the other hand, two external knowledge sources lower survival chances. Both regionally endowed technological-innovation (*INN TECH*) and human capital (*EDU*) are negatively related to firm survival, and both serve as selection mechanisms. A location in a region where incumbent firms successfully introduced new products and services into the market seems to lower the survival chances of new comers (in business services). We saw that firms that do survive have higher growth potential due to non-technological innovations. We conclude that, in the case of new business services, firms' locally endowed innovation serves as a mechanism for excluding those entrants unable to adjust successfully in a highly innovative industry (though, when they do, they profit from their location). This is in line with Audretsch and Mata (1995), who found such an effect at the industry level.

Table 7.1 New firm survival and growth, 2001-2006 (std. dev. in parentheses)

	MANUFACTURING			BUSINESS SERVICES		
	(1) Null *GROWTH*	(2) Heckit *GROWTH*	(3) Probit *SURVIVAL*	(4) Null *GROWTH*	(5) Heckit *GROWTH*	(6) Probit *SURVIVAL*
Constant	0.117***	0.248	-2.044*	0.081***	-0.587*	2.772***
	(0.011)	(0.458)	(1.195)	(0.005)	(0.303)	(0.456)
SIZE		-0.104***	0.041**		-0.127***	0.003
		(0.011)	(0.018)		(0.007)	(0.008)
EDU		-1.503***	-1.146		-0.402*	-0.848**
		(0.490)	(0.078)		(0.248)	(0.430)
TECH		0.020	0.023		-0.011	0.014
		(0.023)	(0.042)		(0.010)	(0.024)
R&D		0.009	-0.030		0.006	0.050**
		(0.020)	(0.035)		(0.012)	(0.020)
INN TECH		0.076	-0.229		0.027	-0.264**
		(0.122)	(0.186)		(0.063)	(0.107)
INN NTECH		0.161	0.350		0.256***	-0.191
		(0.158)	(0.248)		(0.075)	(0.151)
UNEMPL		-0.011	-0.077		0.019	-0.026
		(0.033)	(0.055)		(0.016)	(0.033)
REG.GR		0.039	0.069		0.014	-0.007
		(0.039)	(0.063)		(0.015)	(0.035)
JOB DENSE		0.025	-0.068***		0.035***	-0.020
		(0.017)	(0.027)		(0.008)	(0.016)
HBO		-0.007	-0.044		0.004	-0.005
		(0.039)	(0.071)		(0.017)	(0.042)
UNIV		0.006	-0.029		-0.005	0.085
		(0.065)	(0.151)		(0.030)	(0.081)
LAMBDA		0.048	-		-0.524*	-
		(0.268)			(0.316)	
INSTR[a]		-	-0.631***		-	-0.233***
			(0.175)			(0.055)
Industry fixed effects[b]	no	yes	yes	no	yes	yes
ICC	2.1 %	-	-	1.2 %	-	-
Adj. Rj2	-	4.0 %	-	-	3.1 %	-
Adj. Rj2	-	42.9 %	-	-	25.0 %	-
-2*LogLik	5874.70	5688.97	-	43614.14	42770.95	-
N	3386	3386	5098	25315	25315	42698

*** significant at 0.01, ** significant at 0.05, * significant at 0.10. RIGLS estimation. a The instrument in the manufacturing model specification is the average regional number of bankruptcies among the total of establishments for the period 1994-2006. In the business services model specifications, the instrument is the 'new economy' dummy variable. b Industry fixed effects by 2-Digit Nace codes. *EDU* = Educational level, *TECH* = High and Medium Tech, *R&D* = Research and Development, *INN TECH* = Technological innovation, *INN NONTECH* = Non-technological innovation, *UNEMPL* = Unemployment level, *REG GROWTH* = Incumbents job growth 2001-2006, *JOB DENSE* = Job density, *HBO* = Higher Vocational Education, *UNIV* = University.

7.5.2 Testing for robustness

We carried out several robustness checks for our analysis. First, we estimated the same models for the time period 2002-2006 (new entries 2001 and 2002) to check for time robustness. Here, we find that the direction and significance levels of the coefficients remain the same.

Second, for all regional variables, one can argue that a firm's benefits exceed the border of the local unit of analysis (in our case, municipalities). As a result, spatial autocorrelation might lead to misspecification of the models. We carried out checks for spatial autocorrelation by analyzing the significance of spatially weighted versions of the regional variables (linear and quadratic). For each of these variables, the values for the region in which a firm is located (original variable) as well as the average of the values of the neighboring regions (the spatial lag) were included in the models (see Knoben 2008). The lagged versions of the regional knowledge variables turned out not to be significant, and model performance including these lags did not improve over models without[42]. This implies that firms' knowledge spillovers (for example, of the R&D and innovation variables) are confined to borders of the region (in our case municipalities). This is in line with the reasoning of Stam (2007), who finds that new and young firms mainly have local networks. An extension of testing spatially weighted variables is the allowance for hierarchy in relations: the fact that an average indicator does not justify the possibility of knowledge to spill over mainly from focal points (induced by agglomeration effects) to firms in regions less endowed with knowledge sources (Carlino et al. 2007, Bettencourt et al. 2007). We tested for the influence of weight matrices based on linkages from the largest cities (defined as the 30 or 100 municipalities with the largest number of inhabitants) to their surrounding regions, and assume the reverse relation as non-existent. The results of these models generally do not improve earlier results. One argument for the fact that we do not find such effects is that the spatial patterns of our knowledge indicators do not represent a hierarchal system. R&D-activities, for example, are predominantly an non-urban phenomena in the Netherlands, taking place in smaller cities outside core agglomerations (Raspe and Van Oort 2006).

Third, we tested several different instruments (*INSTR*). One of the difficulties related to panel attrition having to do with non-survival and growth of firms is finding instruments that are related to survival, but not to growth. As both phenomena are often considered to be 'in line with one another', it is difficult to find appropriate instruments. We tested for the average regional number of bankruptcies (1994-2006), a 'new economy' variable, and for size-quadrate specifications. The first and second variables were explained earlier. From the size-quadrate variable, one can argue that since our dataset does not allow for testing whether a new firm is a spin-off, large start-ups have a higher probability of being spin-offs or originating from mergers. As spin-offs have higher survival rates (Weterings and Koster 2007), and not higher growth potential per se, this may be a good instrument. We used size-quadrate as a proxy for spin-offs. The coefficients of size-quadrate, though, are not significant in the manufacturing models. Also, the new economy dummy (ICT-hardware production) was insignificant in the manufacturing model. Therefore we chose to use the bankruptcy variable in the manufacturing models and the 'new economy' variable for the business service models.

7.5.3 Knowledge-Intensive Industries

Focusing on the effect of localized knowledge externalities, so far we have analyzed whether (within each region) there is a positive relationship between localized knowledge externalities and firm growth. This relationship might, however, not be a fixed relationship over all regions (fixed meaning that it does not vary over regions). One can argue that some types of firms may profit more than others, and that generalization might disguise specific effects. Although we did not find a relationship between localized knowledge externalities in general, it might be the case that this

42 These results are not included in the table but can be obtained on request.

relationship applies to only some type of firms. We argue that, new firms in knowledge-intensive industries particularly profit from localized knowledge externalities, and not their non-knowledge intensive counterparts.

Multilevel analysis allows for testing these so-called 'cross-level interaction effects': interactions between variables measured in hierarchically structured data at different levels (see Kreft and de Leeuw 2004 and Hox 2002). The first step in analyzing this is to estimate random coefficient models in which the slope of any of the explanatory variables at the micro-level has a significance variance component between regions. We tested for random slopes for all two-digit NACE codes (Appendix 7.4 shows these results). It appears that some of the knowledge intensive manufacturing and business services industries do indeed have significant slope coefficients.

For the variables that have significant slopes, we now test for possible cross-level interaction relations. We do this for those variables that, besides having significant slopes, also have significant covariance between intercepts and slopes, suggesting that regions with higher intercepts also have steeper slopes (or lower slopes in the case that regional characteristics restrict growth). It turns out that only NACE codes 33 (medical instruments industry) and 73 (research and development industry) have significant covariance. Both are highly knowledge-intensive industries. To test whether these covariances exist due to localized knowledge sources, cross-level interaction effects are included in the earlier models.

Table 7.2 presents these results; including random slopes and cross-level interaction effects for industry dummies 33 and 73 (the models have slightly improved fits as compared to table 1). Regarding the growth of new 'medical instruments production' firms, table 7.2 (model 7) shows that, though we expected significant cross-level interaction effects (since the covariance between intercept and slope was significant), none of the additional effects are significant. Though, for these type of firms, region is of special importance, this is not captured by knowledge externalities like human capital (*EDU*), technological sources (*TECH*, *R&D*), innovation (*INN TECH*, *INN NTECH*), or the presence of educational institutions. This means that for new firms in this industry, these localized sources have no additional growth potential. Concerning 'research and development activities' (*NACE 73*), model (8) reveals that the same situation seems to be the case. We do find, however, that the interaction effect for a location near a university is highly significant. Just as the Knowledge Spillover Theory of Entrepreneurship states that this externality enhances entrepreneurial activity, we find indications that new firms in 'R&D'-related activities indeed profit from this knowledge source, as it enhances new firms' post-entry growth. New knowledge-driven firms, active in research and development industries but less able to perform research and development activities or invest in knowledge sources themselves, profit from university-related externalities. This is in line with research by Acs et al. (2004). Greater numbers of vocational institutions, on the other hand, lower this growth potential.

7.6 Conclusions and discussion

The literature indicates that knowledge externalities can influence firms' location decisions, since knowledge predominantly spills over locally and firms tend to locate in proximity to one another in order to capitalize on the knowledge stock of neighboring firms and other sources. Especially for

Table 7.2 Random slope cross-level interactions in the growth models (std. dev. in parentheses)

	MANUFACTURING	BUSINESS SERVICES
	(7) Heckit GROWTH (random slope and interaction for *NACE 33*)	(8) Heckit GROWTH (random slope and interaction for *NACE 73*)
Constant	0.211	-0.585**
	(0.451)	(0.303)
SIZE	-0.103***	-0.127***
	(0.011)	(0.007)
EDU	-1.567***	-0.343
	(0.471)	(0.250)
TECH	0.024	-0.009
	(0.025)	(0.010)
R&D	0.011	0.004
	(0.020)	(0.012)
INN TECH	0.064	0.032
	(0.117)	(0.063)
INN NTECH	0.188	0.247***
	(0.150)	(0.074)
HBO	0.003	0.006
	(0.043)	(0.017)
UNIV	0.005	-0.009
	(0.088)	(0.031)
*EDU*Industry*	-1.548	0.643
	(1.653)	(0.879)
*TECH*Industry*	-0.106	-0.084
	(0.120)	(0.088)
*R&D*Industry*	-0.108	0.115
	(0.093)	(0.079)
*INN TECH*Industry*	0.696	-0.153
	(0.526)	(0.345)
*INN TECH*Industry*	-0.964	0.481
	(0.724)	(0.443)
*HBO*Industry*	-0.154	-0.237**
	(0.186)	(0.103)
*UNIV*Industry*	0.222	0.382**
	(0.314)	(0.188)
UNEMPL	-0.005	0.017
	(0.034)	(0.016)
REG.GR	0.029	0.018
	(0.034)	(0.015)
JOB DENSE	0.026	0.032***
	(0.017)	(0.008)
LAMBDA	0.057	-0.516*
	(0.251)	(0.317)
INSTR[a]	-	-
Industry fixed effects[b]	Yes	Yes
-2*LogLik	5665.49	42758.34
N	3386	25315

*** significant at 0.01, ** significant at 0.05, * significant at 0.10. RIGLS estimation new firms, strategies for acquiring or leveraging external resources are important. The Knowledge Spillover Theory of Entrepreneurship provides a framework for analyzing this in its statement that entrepreneurial activity will tend to be greater in contexts where investments in knowledge are relatively high and where new firms can profit from spillovers. External knowledge sources that trigger entrepreneurship are also assumed to be important for processes subsequent to entry. Survival and growth prospects of new firms will depend on their ability to absorb external knowledge and transform it into competitive advantages. Since spillovers of knowledge are assumed to be spatially bound, proximity can play an important role in firms' survival and growth.

In this paper, we analyzed new firms subsequent to their entry (survival and growth analysis) and empirically tested whether locations rich in knowledge endowments facilitate better entrepreneurial performance.

Although the external environment explains only a marginal proportion of the variation in firm performance, it can still be argued that the local context contributes to firm performance as a solitary factor after taking into account between-firm heterogeneity: 2.1% of the variance in the growth of new manufacturing firms can be assigned to area-effects; for business services, this impact is 1.2%. Although the spatial effect for manufacturing is larger than that for service firms, we do not find that external knowledge sources enhance growth (and survival) potential. New services firms, on the other hand, seem to profit more from knowledge externalities. On the other hand, we find indications that regions with a large number of innovators are negatively related to firms' survival chances, which serves as a selection environment. Locating in a region where incumbent firms have successfully introduced new products and services to the market lowers the survival chances of new comers (in business services). In the case of new business services firms, regionally endowed innovation thus serves as a mechanism for excluding those entrants unable to adjust successfully in a highly innovative industry (though when they do, they profit from their location). This is consistent with Audretsch and Mata (1995), who found such an effect at the industry level.

For cities (municipalities), we further find that knowledge-intense contexts enhance the growth of new firms, subject to distinctions in types of knowledge externalities (more positively related to (non-technical) innovation than to technologically related R&D, type of start-ups (larger knowledge contextual effects in business service firms than in manufacturing firms), and type of post-entry process (different effects on survival and growth). We also find significant interaction effects between the growth of R&D-specialized firms with university presence. We further conclude that indications that factors promoting new firm formation differ from those that enhance the post-entry performance of early stage companies. New firms in geographically crowded areas, though benefiting from proximity to knowledge externalities, suffer from the competition inherent in a heavy concentration of nearby competitors (both incumbent and other new firms).

As entrepreneurship and innovation become increasingly popular among (regional) policymakers, who claim that these are crucial factors for generating sustained economic growth, our results suggests that at the level of the firm the conventional wisdom that new firms profit from knowledge externalities does not hold for all types of firms and contexts. First, knowledge externalities also affect non-survival. Second, we find indications that spillover potential is industry-specific, as we found that cross-level interaction effects are specifically significant for only a few types of industries. We found that only new firms in 'R&D'-related activities profit from proximity to a university. This indicates that heterogeneous processes at the level of entrepreneurs may not align with those of regional planners hoping to develop innovative and high performance regions in general terms.

Appendix 7.1 Multilevel models

The model assumes that we have data from J regions, with a different number of respondents (new firms) n_j in each group. At this firm level, we have the outcome of respondent i in group j, and variable Y_{ij} (survival or growth). There is an explanatory variable X_{ij} at the firm level, and an explanatory variable at the regional-level variable Z_j. To model these data, a separate regression model in each group is formulated:

$$Y_{ij} = \beta_{0j} + \beta_{1j} X_{ij} + e_{ij} \qquad (7.1)$$

The variation of the regression coefficients β_j is modeled using a regional-level regression model:

$$\beta_{0j} = \gamma_{00} + \gamma_{01} Z_j + \mu_{0j} \qquad (7.2)$$

and

$$\beta_{1j} = \gamma_{10} + \gamma_{11} Z_j + \mu_{1j} \qquad (7.3)$$

The firm-level residuals e_{ij} are assumed to have a normal distribution with mean zero and variance σ^2_e. The regional-level residuals μ_{0j} + μ_{1j} are assumed to have a multivariate normal distribution with expectation zero, and to be independent from the residual errors e_{ij}. The variance of the residual errors μ_{0j} is specified as σ^2_e and the variance of the residual errors μ_{0j} and μ_{1j} is specified as $\sigma^2_{\mu 0}$ and $\sigma^2_{\mu 1}$. To write this model as a single regression equation, we substitute Equations (7.2) and (7.3) into equation (7.1). Substitution and rearranging terms gives:

$$Y_{ij} = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j + \mu_{0j} + \mu_{1j} X_{ij} + e_{ij} \qquad (7.4)$$

The segment $\gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j$ in Equation 7.4 contains all the fixed coefficients; this is the fixed (or deterministic) part of the model. The segment $\mu_{0j} + \mu_{1j} X_{ij} + e_{ij}$ in Equation 7.4 contains all the random error terms; this is the random (or stochastic) part of the model. The term $X_{ij} Z_j$ is an interaction term that appears in the model because of modeling the varying regression slope β_{1j} of the respondent-level variable X_{ij} with the group-level variable, Z_j.

Even if the analysis includes only variables at the lowest (individual) level, standard multivariate models are inappropriate. Multilevel models are needed because grouped data violate the assumption of independence of observations. The amount of dependence can be expressed as the intraclass correlation (ICC), ρ. In the multilevel model, the ICC is estimated by specifying an empty model, as follows:

$$Y_{ij} = \gamma_{00} + \mu_{0j} + e_{ij} \qquad (7.5)$$

This model does not explain any variance in Y. It only decomposes the variance of Y into two independent components σ^2_e, which is the variance of the lowest-level errors e_{ij}, and $\sigma^2_{\mu 0}$, which is the variance of the highest-level errors μ_{0j}. Using this model, the (ICC) ρ is given by the equation:

$$\rho = \sigma^2_{\mu 0} / (\sigma^2_{\mu 0} + \sigma^2_e) \qquad (7.6)$$

Our outcome variable Y_{ij} is firm survival and employment growth. In the regression line (1), β_{0j} is the usual intercept and β_{1j} is the usual regression coefficient (slope) for the explanatory variable, and e_{ij} is the usual residual error term. The subscript j is for the region (Dutch municipality), and the subscript i is for individual firms. The difference between this and a usual regression model is that we assume that each region j has a different intercept coefficient β_{0j}, and a different slope coefficient β_{1j} (since the intercept and slope vary across the regions, they are often referred to as random coefficients; see Hox 2002).

For non-linear models, like the probit multilevel regressions Equation (7.4) can be written as (see also Hox 2002):

$$(P_{ij}) = \gamma_{00} + \gamma_{10} X_{ij} + \gamma_{01} Z_j + \gamma_{11} X_{ij} Z_j + \mu_{0j} + \mu_{1j} X_{ij} \quad (7.7)$$

Appendix 7.2 Descriptives

Table 7.3 Descriptives

	N	Minimum	Maximum	Mean	Std. Dev.
GROWTH manufacturing	3386	-2.40	4.56	0.08	0.57
GROWTH business services	25315	-5.28	5.02	0.11	0.57
EDU	426	0.57	0.79	0.65	0.04
TECH	426	-5.22	-1.31	-2.72	0.62
R&D	426	-2.30	2.48	-0.03	0.70
INN TECH	426	3.19	4.41	3.92	0.20
INN NTECH	426	3.67	4.42	4.11	0.13
UNEMPL	426	0.26	2.48	1.24	0.43
REG.GR	426	-1.77	1.45	-0.14	0.35
JOB DENSE	426	2.64	8.03	5.15	1.13
HBO	426	0.00	1.00	0.09	0.28
UNIV	426	0.00	1.00	0.03	0.16

Appendix 7.3 Correlation matrix

Table 7.4 Correlation matrix (n=426)

	1 EDU	*2 TECH*	*3 R&D*	*4 INN TECH*	*5 INN NTECH*	*6 UN EMPL*	*7 REG. GROWTH*	*8 JOB. DENSE*	*9 HBO*	*10 UNIV*
1	1.000	-0.196	0.067	0.238	0.245	0.370	-0.130	0.632	0.433	0.324
2	-0.196	1.000	0.486	0.251	0.127	0.108	0.047	0.019	0.023	-0.003
3	0.067	0.486	1.000	0.308	0.209	0.229	0.026	0.153	0.212	0.190
4	0.238	0.251	0.308	1.000	0.738	-0.071	0.010	0.486	0.204	0.130
5	0.245	0.127	0.209	0.738	1.000	-0.131	0.048	0.413	0.209	0.144
6	0.370	0.108	0.229	-0.071	-0.131	1.000	-0.029	0.258	0.379	0.246
7	-0.038	-0.027	-0.150	-0.105	-0.085	-0.125	1.000	-0.090	-0.104	-0.036
8	0.632	0.019	0.153	0.486	0.413	0.258	0.147	1.000	0.406	0.303
9	0.433	0.023	0.212	0.204	0.209	0.379	0.065	0.406	1.000	0.475
10	0.324	-0.003	0.190	0.130	0.144	0.246	0.053	0.303	0.475	1.000

Appendix 7.4 Knowledge intensive industries

Table 7.5 Significant random slopes and covariance by industries

NACE	**15**	**17**	**18**	**19**	**20**	**21**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**34**
Type	PL	PL	PL	PL	PL	PC	PP	PP	PC	PC	PP	PL	PK	PK	PK	PK	PK	PK
RS	n.s	n.s	n.s	n.s	n.s	n.s	n.s	yes	yes	n.s	yes	n.s	n.s	n.s	yes	n.s	**yes**	yes
Cov	n.s	n.s	n.s	n.s	yes	yes	yes	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	n.s	**yes**	n.s
NACE	35	36	37															
Type	PK	PL	PL															
RS	n.s	n.s	n.s															
Cov	n.s	n.s	n.s															
NACE	64	65	66	67	70	71	72	73	74									
Type	PI	IC	IC	IC	IK	IK	IK	IK	IK									
RS	n.s	n.s	n.s	n.s	n.s	yes	n.s	**yes**	n.s									
Cov	n.s	n.s	n.s	n.s	n.s	n.s	n.s	**yes**	n.s									

n.s. = not significant, PL = Labor intensive production, PC = Captial-intensive production, PP = Knowledge-intensive proces industry, PK, Knowledge-intensive production, IC = Information activities -coordinating-, IK = Information activities -knowledge services-, (Van Oort 2004), RS = Random Slope, Cov is Covariance between intercepts and slopes

8 Summary and conclusions

8.1 Introduction

In the emerging knowledge economy, the accumulation and transfer of knowledge are considered to be important for economic growth. It is stressed, though, that knowledge does not diffuse instantaneously around the world; instead, it 'agglomerates'. For this reason, regional and geographical proximity have (re)emerged in the literature as important conditions of knowledge diffusion (Boschma 2005). Regions, as collectors of knowledge externalities, contain traded and untraded firm external circumstances that can alter firm performance, typically resulting from the collective action of other firms and institutions. With the right abilities, firms can complement their internal capabilities with external ones to integrate and utilize different types of knowledge. This suggests that, for a firm, being located in a region rich in knowledge resources is more conducive to performance than being located in a region that is less endowed with knowledge resources.

In this final chapter, the findings of the preceding chapters are summarized. First, our perspective on the knowledge economy and our general research question will be recalled, placing this dissertation within the debate on the spatial impact of the rise of the knowledge economy. Section 8.3 stresses that the research topic is intrinsically multilevel in nature and elaborates on what this means and what types of relationships matter according to our research question. Section 8.4 discusses the empirical results that focus on the impact of spatial knowledge circumstances on firm performance. This will be placed within a discussion on the magnitude of 'the value of location' (section 8.5). In section 8.6, the preceding results and findings will be linked to implications for regional economic development outcomes.

We emphasize that this research will result in a better understanding of the knowledge conditions that shape (spatial) economic development. Within our multilevel approach, both spatial and firm-level approaches are complementary, and the firm-regional interaction in particular is where this dissertation tries to contribute. Conceptually, this means that both firm-specific and context-specific (knowledge) characteristics mutually and simultaneously interact, resulting in performance gains at the firm level.

8.2 The spatial impact of the knowledge economy

This dissertation focuses on the 'economic value of location' from a knowledge-economic perspective. Over the years, a burgeoning literature has confirmed a positive correlation between geographical and urban clustering, the agglomeration of knowledge and regional development in terms of productivity, economic growth and innovation (see Van Oort 2004). Chapter three, presenting a spatial econometric analysis in line with this previous research, underpins these insights. Significant differences in spatially correlated patterns of 'knowledge' intensities were found. These knowledge intensities differ according to the various ingredients that capture the phenomena of the knowledge economy, as defined in chapter three. In short, eight indicators extracted from the empirical literature that connect the knowledge economy and regional economic development are:

1. Educational level. A highly educated workforce has more opportunities to absorb and use information.
2. Communicative skills. These capabilities complement the educational aspects due to the ability to persuade and convince others (and therefore select information).
3. Creative capital. Recently, creativity has been indicated as a driver for innovation and economic growth, besides educational skills as such, with an added value on its own.
4. Information and communication technologies (ICT). As general-purpose technology, ICT can be related to economic performance, especially functioning as an optimal vehicle of knowledge transfer when information is codified.
5. Research and development (R&D). Often indicated as the main knowledge source for economic renewal.
6. High- and medium-tech economic activities. This indicate the representation of technology firms and technology-driven international networks and exports.
7. Technological innovation. Representing the actual innovative output of firms.
8. Non-technological innovation. Representing managerial and organizational renewal and more services-related renewals.

These eight indicators can be summarized in three (statistically independent) dimensions of the knowledge economy: (1) the 'R&D' dimension, comprised of R&D employment indicators and the definition of high-tech sectors; (2) the 'innovation' dimension, comprising both technological and non-technological innovation (bringing new products to the market combined with organizational renewal); and (3) a 'knowledge-workers' dimension, summarizing the level of education of the working population, ICT-related employment and skills related to handling information as well as creativity.

The 'knowledge workers' dimension shows a hierarchical structure according to the level of urbanization: the highest average factor scores are observed in cities and in larger agglomerations (like the Randstad region). Cities like Amsterdam and Utrecht as well as their suburban surroundings have relatively high scores on this dimension. The 'innovation' dimension shows a different spatial pattern. Innovative firms are especially concentrated in regions in the western (the Randstad) and eastern parts of the Netherlands. Municipalities in the Randstad region, cities and central areas of urban agglomerations come to the fore as the foci of innovative activities. The urban hierarchy in this pattern is less distinctive than in the case of the knowledge workers dimension. Finally, the spatial pattern of the 'R&D' dimension again differs from both other dimensions. The regions in the western part of the Netherlands, which showed strong orientations to the knowledge workers and innovators dimensions, are characterized by relatively low degrees of R&D activities. While not the most populated and job-dense parts of the Netherlands, the regions in the southern and eastern parts of the country rank highly in (relative) R&D employment specialization. The Eindhoven region (with multinational firms Philips and ASML and a technical university) and several other cities containing technologically oriented multinational firms and technical universities (like Twente, Wageningen, Delft and Terneuzen) are R&D hotspots in the Netherlands. An urban hierarchy does not apply to this dimension.

Chapter three relates these three knowledge dimensions to economic employment and productivity growth. An interesting outcome is that, despite the often stressed regional economic significance of technological R&D externalities, the dimensions of 'innovation' and 'knowledge workers' are more profoundly related to urban employment and productivity growth. Especially, regions with an endowment of human capital and innovative firms in recent years showed high economic development rates.

Although the simultaneous differentiation of urban knowledge variables into the dimensions of 'R&D', 'innovation' and 'knowledge workers' makes a valuable contribution to the current analytical debate, it does not solve one of the main issues in the economic externalities discussion. Namely, findings at the aggregated (regional) level cannot be interpreted as micro-level evidence. This phenomenon has been referred to in the literature as the 'ecological fallacy'. A correlation found at the regional level does not necessarily have the same meaning as a correlation at the individual level. In other words, there is a need to gain more insight into which types of firms profit from externalities and which do not. Arguments that 'the region matters' should therefore not be deduced from a macro-level phenomenon of, for example, regional clusters, but also induced from micro-level 'evidence'. This fits with recent arguments that theories that underlie externalities are microeconomic in nature (Rosenthal and Strange 2004, Duranton and Puga 2004). This implies that the relationship between spatially bounded externalities and economic performance should actually and most profoundly hold at the micro or firm levels (Audretsch et al. 2006, Beugelsdijk 2007). In line with this argument, the central research question in this dissertation is:

> How are localized knowledge sources mutually and simultaneously related to economic growth processes at the regional and the firm levels?

The aim of our research is to contribute - both conceptually and empirically - to the understanding of the effects of agglomerated knowledge circumstances on firm-level and regional-level economic performance. The most profound contribution of the dissertation concerns the inclusion of the firm in an urban economic growth framework in the Netherlands, addressing multi-level and cross-level interactions of explanatory variables. At the conceptual level, this can be considered to be an intrinsic multilevel issue containing different kinds of macro-micro relationships. Empirically, this research tests some of the underlying assumptions by estimating random effects or multilevel models and using data at the establishment level simultaneously with the three kinds of agglomerated knowledge variables (the dimensions of R&D, innovation and knowledge workers).

8.3 An intrinsic multilevel problem

This dissertation fits into the lines of research followed by regional economics and economic geography. However, by acknowledging contextual effects - or spatially bounded externalities - it becomes apparent that the outcomes under study are associated with processes operating at multiple 'levels': an individual (firm) level and an aggregated (regional) level. One can consider this as a multilevel problem that concerns the relationships between variables that are measured at a number of different hierarchical levels. Figure 8.1 shows these multilevel propositions conceptually. Possible relationships in such research frameworks include the already-mentioned macro variables influencing macro variables (relationship 1: the relationship between the knowledge economy, emphasizing the agglomeration of knowledge, and regional economic development, the traditional focus in regional economics and economic geography studies). Also, at the micro level, there is the influence of micro variables on other micro variables (relationship 2: the relationship between firm behavior and economic performance). Both relationships are complemented by the multilevel propositions that macro variables can influence micro variables and vice versa (relationships 3 and 4).

The macro-micro interaction is especially relevant for our research question: the effect of agglomerated knowledge on firm performance, and within this relationship, the hypothesis that firm-specific characteristics and relationships (micro-micro) vary interactively with agglomerated knowledge variables. Adopting a multilevel perspective will provide insights into if and how the region matters (from a knowledge economical perspective) for firm performance.

The way in which firm performance influences the economic development of regions is made explicit in this study to make 'the evidence' less indirect, no longer treating the region as a 'black box' (Breschi and Lissoni 2001). The multilevel approach in this research additionally shows the possibilities for empirical operationalization, which are often lacking in single-level regional approaches (Markusen 1999, MacKinnon et al. 2002).

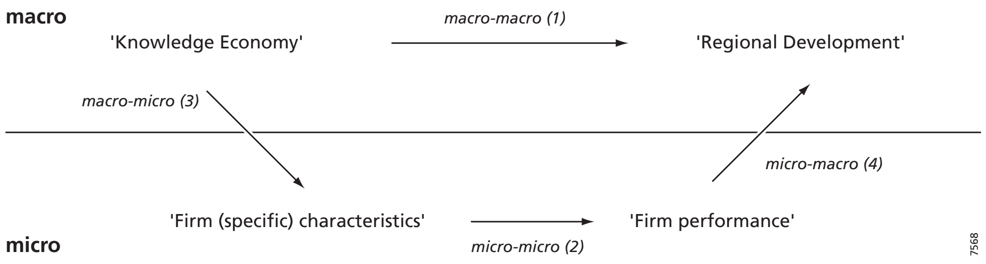

Figure 8.1 Macro-micro propositions

Analyzing multilevel problems or theories requires a multilevel research framework. Chapter 2 demonstrated the four advantages of multilevel statistical modeling:

1. Multilevel analysis, unlike more standard single-level methods, was explicitly developed to resolve fallacies, such as the ecological and atomistic fallacies[43]. By working at more than one level simultaneously, an overall model can handle the micro-scale of firms and the macro-scale of places;
2. Multilevel analysis is able to distinguish between genuine observed differences between places and those that are merely artifacts of within-place characteristics (the composition of a place). The method is thus able to separate the context from composition effects by decomposing the micro-level variance;

43 Chapter 2 elaborated on ecological and atomistic fallacies. As we explained earlier, 'ecological fallacies' can occur within the interpretation of aggregated data, while the 'atomistic fallacy' occurs when the hierarchical structure of the data has not been taken into account. This might lead to errors in sample size treatment, providing over-optimistic estimates of significance and correlated errors of firms belonging to the same context. Conceptually, this is the reciprocal of the ecological fallacy, involving the danger of drawing false conclusions as there is no necessary correspondence between individual-level and group-level relationships.

3. Multilevel analysis allows relationships to vary according to context in a twofold manner: first, some places may have uniformly higher rates of firm performance than others (random intercepts models), and second, places can make a difference for relationships of certain types of firms (random slopes models). A particular strength of the multilevel approach is that aggregated units, such as regions, remain in the analysis as identifiable entities;
4. Multilevel analysis is able to control in a natural way for firm-specific characteristics, within and between levels of measurement (the latter is captured by so-called cross-level interaction effects). Firm internal competences or characteristics therefore can be conceptualized as prerequisites for the successful absorption of localized externalities.

8.4 From macro to micro

Chapters 4 to 7 contain empirical research on the impact of agglomerated knowledge on firm performance. Our general conclusion is that there exists an effect of the 'economic value of location' and that this can be related to spatial knowledge conditions. The relationship between firm performance and geographical contexts is still very complex as it is subject to distinctions in types of knowledge externalities (the dimensions of 'knowledge workers', 'innovation' and 'R&D'), type of firms (manufacturing or business services, with underlying distinctions in incumbent and new firms), type of post-entry process of success (survival and subsequent growth) and type of performance (employment growth or productivity). All of these nuances (and interactions between them) play a role when analyzing the impact of localized knowledge sources on firm performance.

8.4.1 Spatially bounded externalities

Table 8.1 summarizes the results of the empirical findings on the impact of spatially bounded externalities. The most robust finding is that firms experience higher performance rates when located in an urban region with a higher intensity of other successful innovators, an external effect that is related to proximity to other firms that successfully introduce new products or services to the market. Regions thus seem to function as a collective territorial innovation system that provides externalities from which individual firms profit. These findings fit into research traditions of territorial innovation systems that stress advantages of clusters in a spatial context (see Breschi et al. 1998, Malerba and Orsenigo 1997, Cooke 2001, Moulaert and Sekia 2003). This literature argues that yields from innovative success can be reinvested, thereby increasing the probability of future innovation. At the local level, this leads to cumulativeness within specific locations, with a high degree of inter-firm knowledge spillovers.

It also becomes apparent that although agglomerated innovation seems to be a robust growth enhancing factor for surviving new firms, it is negatively related to a firm's survival chances in the first place. One can say that the region also functions as a selection mechanism, excluding those entrants unable to adjust successfully to market pressures in a highly innovative region.

Concerning the R&D-knowledge dimension, the results indicate that spatially bounded 'R&D' externalities in general terms are less profoundly related to positive firm performance but have a positive impact on the employment growth rates of incumbent firms in business services. A possible explanation for this finding is that although R&D activities are often associated with manufacturing industries, R&D as an industry is classified as a knowledge-intensive business services activity (NACE code 73). These types of activities seem especially sensitive to local R&D circumstances. This phenomenon is in line with propositions by Audretsch and Dohse (2006), Simmie (2002), Audretsch (2003) and Feldman (1994). The empirical findings in chapter 7 also underpin these results: new firms that are active in research and development industries profit from university-related externalities. This agglomerated R&D effect also enhances the survival chances of new business services firms, which, though a bit tentative, fits the perspective of the Knowledge Spillover Theory of Entrepreneurship.

Besides the dimensions of 'innovation' and 'R&D', the effect of the human capital-related dimension of 'knowledge workers' (regions with a high level of education of the workforce and a high level of use of ICT and containing creative and communicative skills) was tested. At the level of the firm, there exists a significant and positive relationship of this dimension with the employment growth of incumbent business services firms. The finding that services firms in particular profit from (external) human capital dimensions is in line with research by, for instance, Muller and Doloreux (2009), Glaeser and Kohlhase (2004) and Kolko (2000). Common arguments in this line of research are that co-location is profitable for business services because of the use of the same types of educated workers (human capital) and the still-high costs of moving people, and because knowledge-intensive business services in particular involve face-to-face contacts (see also Storper and Venables 2004). Remarkably enough, the human capital dimension also has a negative effect on the (survival and) growth of both incumbent and new manufacturing firms and on new business services firms. These types of activities have lower growth rates in regions that can be characterized by a specialization in the human capital dimension. As chapter 3 indicated, these regions are urban in character, so the negative relationship might be attributed to competition between firms over vital (knowledge) sources in cities. In that sense, and in line with the 'geography of opportunity' literature, the location of a firm might also have a negative influence. This literature indicates that organizations also compete with one another for vital (knowledge) resources (Sorenson and Audia 2000). Since organizations compete more intensely within local population boundaries, their location can also be a growth constraint (for example, in acquiring specific knowledge and human capital). Stuart and Sorsenson (2003) stated that factors promoting new venture formation differ from those that enhance the post-entry performance of early stage companies. New ventures in geographically crowded areas, though benefiting from proximity to knowledge externalities, suffer from the competition that goes along with a heavy concentration of nearby competitors (both incumbent and other new firms). These kinds of effects were not tested directly in our research but are worth investigating in future research.

8.4.2 Firm-specific characteristics

To finalize our empirical findings, the relationship between the firm and its spatial context differs for firm-specific characteristics. Stemming from figure 8.1, several firm-specific characteristics were included in the multilevel models. From a multilevel perspective, these are important in two ways:

1. As single micro-micro relationships that are simultaneously included with regional knowledge circumstances, and
2. As varying interactively with these regional knowledge circumstances. This means that micro-micro relationships work out differently according to their spatial context.

In the empirical chapters, both types of relationships were hypothesized in relation to productivity and as prerequisites for interaction with externalities. They will be described here shortly. First, a firm's internal knowledge base is important as knowledge can be considered the most strategically significant resource of a firm (Grant 1996, Nonaka et al. 2000). As such, it is performance enhancing, but it also functions as a firm's absorptive capacity, in terms of both understanding where the potential sources of knowledge reside and the ability to absorb and deploy external knowledge (Cohen and Levinthal 1990). Internal competencies here pre-condition the ability to identify, assimilate and apply know-how generated outside one's own organization.

Second, transfer mechanisms like face-to-face interaction are indicated (Glaeser 1999). Interaction between firms is considered to be fostered by face-to-face interactions, especially where it deals with tacit knowledge (Storper and Venables 2004), McCann and Simonen 2005). In particular, the information used by innovators has a tacit component as it is often difficult to set down in blueprints or to codify completely, and hence it is difficult to communicate at a distance.

Third, contrary to proximity arguments, the adoption of information and communication technologies (ICT) is also stressed as a mechanism for knowledge transfers. It is argued that ICT creates the opportunities to have global network relationships, rendering geographical embeddedness of little importance (Drennan 2002, Black and Lynch 2001). ICT, as a general purpose technology as such, enhances productivity by making working processes more efficient (Van Ark and Piatkowski 2004).

Fourth, the literature indicates more traditional (industrial organization-like) elements that can be related to firm performance. Firm size and age seem especially important (see Audretsch and Dohse 2007 for an overview of this literature). Firm size (representing scale advantages) can be positively related to firm performance, especially productivity (but less so for employment growth, see chapter 4). Also, a firm's age is positively related to its performance (Jovanovic 1982), unless firms suffer from lock-in, which is more the case of very 'old' firms since successful firms are better equipped to serve market niches. This lock-in can be described as the competency trap: becoming quite good at doing any one thing reduces the organization's capacity to absorb new ideas and to do other things (Levitt and March 1996). It often turns out to be difficult to unlearn habits and routines that have been successful in the past but have become redundant over time (Boschma 2004). Specifically in relation to externalities, one can argue that larger and older firms have more opportunities than their smaller and younger counterparts to make their own investments in knowledge. A small or new firm wanting to generate its own knowledge capital will be limited by scale and time. Instead, the use of external knowledge and ideas can leverage a small or new firm's own knowledge capital by standing on the shoulders of giants (Acs et al. 2004, Audretsch et al. 2006). One can therefore argue that small(er) and new firms in particular need local knowledge transfers. As indicated in chapter 7, this might contrast with the arguments of 'absorptive capacity' as one can argue that firms without any major internal competencies or valuable resources (i.e., small or new firms) can survive and thrive if they are favorably located, just as the competitiveness of otherwise identical firms may diverge as a consequence of the way in which differences in location show up in their strategies. Fifth, the type of industry is relevant for firm performance since industries experience different development paths and cyclical influences (Griliches 1979). Industry-specific characteristics capture various technology and knowledge dimensions, such as technological opportunity, appropriability regimes, or the emergence of dominant designs along the technology life cycle (Teece 1986, Breschi et al. 2000). However, some industries also benefit more from geographical circumstances than their

counterparts in other industries (Henderson 2003). One can argue that firms in more knowledge-intensive industries have more incentives to absorb externalities.
Finally, without trying to be exclusive, the literature indicates that product specifications are relevant for external interaction (Grant and Baden-Fuller 2004). Products and services are distinctive in being 'standard', 'custom-made or specifically designed' or even 'co-produced' (including risk-sharing) in relation to their customers. As 'economies of scope' (advantages of a wider variety of goods or services) matter as such, one could argue that the more knowledge-intensive a customization is, the more proximity matters.

Concerning the single micro-micro relationships, one can argue that, as they are included simultaneously with spatial variables in the multilevel framework, they are important for controlling for possible composition effects: the fact that regional differences come forth out of firm characteristics. Firm size, age and industry memberships in particular influence this composition. The preceding empirical chapters show that many results are in line with hypotheses stemming from the literature (see those chapters for more elaboration on these). In short, firm age is negatively related to exit rates. This means that the probability of failure decreases with firm age. In addition, age is negatively related to employment growth, meaning that young firms grow faster than their larger counterparts. Firm growth tends to decline as the firm evolves over its life cycle. On the other hand, firms experience 'economies of scale' as larger firms are more productive than smaller ones. Concerning new firms, in line with the literature, our research shows that larger start-ups have higher survival rates but smaller employment growth rates.[44]

Concerning absorptive capacity, measured by the relative quantity of knowledge-intensive jobs, a positive impact was expected, though such a correlation was not found in the empirical analysis. The internal knowledge base in general terms does not foster productivity. Some robustness checks showed, though, that the size-effect - related to the firm's knowledge base - captures part of this capacity and not the amount of knowledge-intensive occupations as such (due to multicollinearity problems, the number of knowledge-intensive jobs[45] and size were not included simultaneously). Another finding is that models with no sectoral fixed effect showed a positive sign of knowledge-intensive jobs. In other words, the firm's internal knowledge base, often related to its absorptive capacity, is a complex variable that is related to the size of the firm and its industrial family characteristics.

Face-to-face interaction, measured by the amount of face-to-face contact relative to the total amount of business-to-business interaction, which is often indicated as a vehicle of tacit knowledge exchange, was also not significant. In other words, face-to-face interaction is not an adequate condition for performance on its own. However, it was shown that the use of ICT enhances firm productivity. The more ICT firms use, the higher their productivity.

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44 However, we also find some contradictions, such as the finding that that larger incumbent firms have a lower probability to survive than larger ones. We argue that the size-quadratic term has the 'right' sign: a positive relationship with survival. This implies that the negative effect of size on growth diminishes for larger size classes. This may be one of the reasons why medium-sized Dutch firms (10 to 100 employees) in particular had difficulties in surviving during the research period.

45 This variable is significant when size is excluded from the models.

8.4.3 Interaction effects

As indicated, a special interest in this research is on individual characteristics related to firm performance, but varying interactively with regional knowledge circumstances. To test for these kinds of effects in the empirical models, interaction effects were included. According to these cross-level interactions, the most robust finding in the empirical models is that smaller firms, and not their larger counterparts, especially benefit from localized knowledge externalities. One can argue that this latter group often has a broader (and deeper) internal knowledge base. Additionally, the spillover potential seems to be industry-specific, as the cross-level interaction effects specifically are significant for only a few types of industries. Just as the Knowledge Spillover Theory of Entrepreneurship states that indications were found that new firms in 'R&D'-related activities profit from this knowledge source, it enhances new firms' post-entry growth. New knowledge-driven firms, active in research and development industries but less able to perform research and development activities or invest in knowledge sources themselves, profit from university-related externalities. This is in line with research by Acs et al. (2004). Also, financial services firms profit from a location with a higher intensity of 'knowledge workers'. Proximity to other firms, characterized by a highly educated, communicative and creative workforce using ICT, has advantages for financial services firms.

These multilevel analyses showed the added value of the empirical framework applied, as the controlling for firm heterogeneity and the allowance for micro relationships varying interactively with regional knowledge circumstances led to more detailed insights into the embeddedness of firms in their urban regions and the degree to which they could potentially profit from knowledge externalities. In the next section, these findings are situated within the debate on the magnitude of the value of location.

Table 8.1 Summarizing presentation of the empirical results: magnifying glass on spatial knowledge indicators

Knowledge dimensions (dimensions)	**Regions CHAPTER 3**		**Firms: Incumbents -CHAPTERS 4, 5 and 6**					**Firms: New Firms -CHAPTER 7**			
			Manufacturing		Business Services		Total	Manufacturing		Business Services	
	Employment Growth	Productivity Growth	Survival	Employment Growth	Survival	Employment Growth	Productivity	Survival	Employment Growth	Survival	Employment Growth
RESEARCH & DEVELOPMENT	0	--	0	0	0	++	0	0	0	++[1]	0
INNOVATION	++	++	++	++	++	++	++	0	0	--[2]	++[3]
KNOWLEDGE WORKERS[4]	++	++	-	--	0	++	-	0	--	--	-

8.5 Macro-micro effects: the impact of location

An important outcome of this research is that there is substantial heterogeneity, especially at the level of the firm (but also spatially), that is behind the relationship between the emergence of the knowledge economy and regional-economic development. As was mentioned earlier, one of the advantages of multilevel modeling is that it enables us to assess the relative importance of the region at the macro level by decomposing the variance into (firm) composition- and place-specific effects. The place-specific effect can be indicated by what is called 'the intraclass correlation' (an indicator of 'the economic value of location' in our case). The model used to determine the intraclass correlation is a model that contains no explanatory variables at all, the so-called intercept-only model or null model (Hox 2002). These types of models do not explain any variance; they only decompose the variance into two independent components: the variance of the lowest level errors and the variance of the highest level errors. The intraclass correlation is equal to the estimated proportion of the higher level variance compared to the estimated total variance. Table 8.2 summarizes the values presented in the different empirical chapters.

From table 8.2, we learn that approximately 2.5 percent of a firm's productivity and approximately 1 percent of its employment growth can be purely assigned to the firm's location (spatial context). External economies on the firm level thus do exist and are locally bounded on the spatial scale of urban municipalities. In line with findings by, for instance, Moowah (1981), Kim (1997) and Ciccone and Hall (1996) on the spatial level, the empirical results of the multilevel analyses indicate that the relationship between agglomeration effects and firm performance indeed also holds at the firm level. Even in a relatively small country like The Netherlands (with its polycentric urban structure and relatively uniform distribution of cultural, housing and urban-economic amenities), location matters for potential firm-level productivity and growth advantages.

An important question is whether the observed locational impact is also substantial from the individual (firm) perspective. One can say (in line with the findings in the empirical models in this research) that of course firm internal matters are dominant in their performance, but even as such there is a spatial effect that enhances firm performance. In the literature, there is a large debate on

Table 8.2 Intraclass correlation

	Incumbent firms		**New firms**	
	Manufacturing	Business Services	Manufacturing	Business Services
Productivity[5]		2.3%		.
Employment growth[6]	< 1.0%	< 1.0%	2.1%	1.2%

(Footnotes)
1 In this 'Research and Development' dimension, the high- and medium-tech firms distinction is excluded.
2 Technological innovation.
3 Non-technological innovation.
4 For new firms, the 'knowledge workers' dimension is indicated by the educational level of the workforce only.
5 Intraclass correlation for productivity growth is < 1.0%.
6 Not presented in chapter 3, but calculated for this chapter.

magnitude (and mechanisms) of effects of agglomeration on economic activity (see Crawford 2006 for an overview of these studies). Regarding (labor) productivity, at least two studies are of key importance as references. Ciccone and Hall (1996) found that a doubling of employment density increases average productivity by around six percent, and Combes et al. (2005) suggested a more conservative figure of three percent. Taking into consideration the fact that our models are not directly comparable to this other research (due to differences in spatial scale, time period, research region, industries, measurement of the variables, etc.), the 2.5 percent impact of externalities fits in general terms with the findings of these other studies.

8.6 From micro to macro

So far, little attention has been paid to the interaction between micro fundamentals and their collective results: 'the micro to macro' relationship (relationship 4 in figure 8.1). As the core of this dissertation is to conceptually and empirically add micro links to regional development questions, micro-macro relationships are important, first, to indicate what the research findings so far mean for macro level outcomes (in our case: regional economic development), and second, to analyze all relationships in figure 8.1.

One can say that the importance of using micro-level processes to explain macro-level outcomes has especially been recognized in the domain of social science (Wippler and Lindenberg 1987, Coleman 1990). This research discipline traditionally has a stronger interest in dealing with questions of how individual actions aggregate into collective outcomes. What can be learned from these social science applications is that there are several types of transformations from micro to macro levels. Groenewegen (1997) distinguished four types:

1. Aggregation, in which individual behavior is transformed to a distribution through the application of a mathematical transformation;
2. Partial definition (or definition by convention): When the incidence of an individual effect reaches a certain level, a collective effect is supposed to exist by definition;
3. The application of institutional rules: In this case, the transformation is not made through an arbitrary definition, but is based on an institutional rule (for instance, a majority rule);
4. Game theory and simulation: The analogy of a game can be used to predict the collective outcomes of joint individual actions.

When discussing what firm-level processes and performance imply for the rise, growth and decline of regions or spatial clusters, we suggest that type (1) transformations are especially relevant. In short, the summation of micro (firm) performances leads to a macro outcome (regional performance). When the external effects have been rightly and fully taken into account at the firm-level (of all firms in a region), aggregation should lead to the regional effects of these externalities. The same reasoning the other way around, though, does not hold: in high performing regions, there can still be many low performing firms. It can even be the case that the high performance rate of firms can be caused by only a few (for instance large) firms. Many research problems in social sciences are different in nature and deal with type (2)-(4) transformations in order to address a theoretical problem of explaining when a macro phenomenon occurs. Transformation by aggregation therefore can be considered to be an exception within micro-macro links (Groenewegen 1992), but seems to be applicable to our research framework.

However, there are some reasons why the performance of a regional stock of firms does not simply add up to regional economic performance. First, the dynamics resulting from firm demography are ignored. In a spatial context, firm demography consists of the growth and exit of firms (as was measured empirically in our empirical analyses), but also of the entry of new firms and the relocation of existing ones (Van Wissen 2002). These two processes (endogenously) influence the macro-level regional outcome. Both are additional drivers of regional economic development, and both are subject to spatial selection and sorting effects (Baldwin and Okubo 2006, Knoben 2008). For instance, the most efficient firms are the ones that move first to the regions that are endowed with the largest agglomeration effects. On the other hand, Combes and Duranton (2006) argued that despite the advantages of agglomeration (for example, labor market pooling), firms may make the strategic decision to locate in different local labor markets to avoid labor market poaching. This means that there is an even greater urge to control for firm-level heterogeneity.

This discussion indicates that it is important to distinguish between static and dynamic interpretations of our analysis. Our empirical contributions are mainly static in the sense that they do not deal with the fact that firm performance (or its aggregated regional representative) can also influence firm behavior (and demography) in a subsequent period. This dynamic (evolutionary) perspective can build on the demographic perspective by focusing on changing spatial patterns resulting from entry, growth, exit and migration of firms (Frenken and Boschma 2007). Within such a framework, Maskell and Malberg (2007) offered the interesting insight of including, in addition to micro-level processes, higher-order processes at the level of the cluster or region taken as a whole, e.g., the creation of supportive institutions, local culture and the establishment of the place as a brand of the dominant local industries. Such factors reinforce the specialization or knowledge base of a region, and by doing so they might change the regional position in the future. This implies an ambitious research agenda to explore the causal link between 'institutions' and economic growth (Glaeser et al. 2004, Bathelt 2006).

Second, our research design (in which firms are regionally embedded) can be considered as a starting point for statistical modeling of complex reality. It might be the case that firms are members of more than one higher classification unit, so that a strict hierarchy of firms within regions is no longer sufficient. These models are known as multiple membership models (Browne et al. 2001, Fielding and Goldstein 2006). For instance, firms are not only hieratically nested in regions, but are part of value chains, institutional or industry-related networks, etc. These memberships are often a-spatial and more nationally or internationally organized. In short, firms can experience enhancing externalities stemming from multiple memberships. These can be modeled simultaneously with their multilevel structure of embeddedness in the region. Regions as collectors of high-performing firm experience add value when the firms that are located in the region profit from other types of networks. This type of modeling is recommended for future research.

Notwithstanding these lines for further research, we conclude that the research presented here contributes - both conceptually and empirically - to a better understanding of agglomerated knowledge circumstances on firm-level and regional economic performance. The chosen multilevel approach enabled us to assess the relative importance of the region, which is characterized by different knowledge dimensions.

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Samenvatting in het Nederlands

De regionale kenniseconomie; een multilevelperspectief op het presteren van bedrijven en lokale kennisexternaliteiten

Introductie

De productie, de distributie en het gebruik van kennis en informatie zijn de afgelopen decennia steeds centraler komen te staan in het functioneren van veel westerse economieën. Om die reden wordt wel gesproken over 'de opkomst van de kenniseconomie' (OECD 1996, 1999). Verschillende auteurs typeren deze transitie in de economie als hét dominante postindustriële ontwikkelingsparadigma; een paradigma dat ontstond in de jaren '80 van de vorige eeuw en dat in de komende decennia voor bedrijven bepalend zal zijn (Harris 2001, Karlsson et al. 2005). In het kort komt het erop neer dat de creatie en de distributie van 'kennis' de belangrijkste aanjagers zijn in processen van economische groei. 'Kennis' wordt daarmee een van de meest strategische factoren voor het functioneren en presteren van bedrijven (Grant 1996).

Hoofdstuk 1 van dit proefschrift gaat over de opkomst van de kenniseconomie, en enkele gerelateerde economisch-theoretische benaderingen. De interne kennisbasis van bedrijven en de vaardigheden die zij hebben ontwikkeld om kennis te absorberen en te internaliseren, zijn hierbij van groot belang. Naast de waarde van bedrijfsinterne bronnen gaat het hierbij ook om externe kennisbronnen, ofwel zogenaamde *kennisexternaliteiten*[1]. Op kennisuitwisseling gebaseerde relaties tussen bedrijven onderling en tussen bedrijven en instellingen als universiteiten kunnen de traditionele grenzen van een onderneming oprekken. Zeker wanneer de producten en diensten die bedrijven ontwikkelen, een breed spectrum vereisen van verschillende typen gespecialiseerde kennis. Een enkel bedrijf heeft al deze kennis en vaardigheden veelal niet binnen zijn eigen 'muren'. Dat benadrukt nog eens het belang van deze kennisexternaliteiten (Grant and Baden-Fuller 2004).

Met name de ruimtelijk-economische en economisch-geografische literatuur hebben sterk bijgedragen aan het debat over kennisexternaliteiten (zie hoofdstuk 1 voor een overzicht van deze literatuur). Uit deze literatuur komt sterk naar voren dat kennis zich niet zo maar tussen economische actoren verspreidt. Een vaak genoemde voorwaarde is dat actoren die kennis uitwisselen, zich in elkaars nabijheid bevinden. Omdat kennis in belangrijke mate persoonsgebonden is, vereist kennisuitwisseling frequent en fysiek contact. De ontwikkeling en uitwisseling van kennis is bijgevolg lokaal en regionaal gebonden (Audretsch et al. 2006). Op regionaal niveau is kennisuitwisseling efficiënt georganiseerd, zeker als het gaat om formele en gerichte uitwisselingen, maar ook in het geval van informele en onbedoelde 'kennisspillovers' (Storper and Venables 2004). Dit leidt ertoe dat kennis als het ware 'agglomereert'. Regio's met veel kennisbronnen zijn daarom in het voordeel: door hun kennisvoorsprong ontwikkelen ze zich in economisch opzicht beter.

Dit proefschrift bouwt voort op deze ruimtelijk-economische en economisch-geografische onderzoekstraditie. Daarbij benaderen we het kenniseconomische vraagstuk van bedrijf en

1 We definiëren kennisexternaliteiten als verhandelbare en niet-verhandelbare bedrijfsexterne kennisgerelateerde omstandigheden, gecreëerd door de aanwezigheid of collectieve actie van andere bedrijven of instellingen (zie hoofdstuk 1).

omgeving vanuit een multilevelperspectief (met bijbehorend multilevel analyseraamwerk; zie hoofdstuk 2). Wanneer een bedrijf voordeel kan putten uit de aanwezigheid van lokaal gebonden of geclusterde externe kennisbronnen (ofwel een ruimtelijk contextueel effect kent), hebben we te maken met (ten minste twee) verschillende schaalniveaus, namelijk het bedrijf (micro) en de regio (macro). Figuur 1.1 toont dit multilevelperspectief. Naast de macro-macro-interactie op ruimtelijk niveau is er ook het microniveau van het bedrijf. Hoewel het in studies waarin geografische eenheden worden gebruikt (macro-macro), niet gebruikelijk is om uit te gaan van dit niveau (Maskell 2001, Taylor and Asheim 2001), is het microniveau desalniettemin van belang; theorieën over externaliteiten zijn in essentie namelijk veelal gericht op dit niveau (Rosenthal and Strange 2004). Het effect van ruimtelijk gebonden externaliteiten zal zich met name voordoen op het niveau van het bedrijf, dat immers de voordelen ervaart (Audretsch et al. 2006, Beugelsdijk 2007).

Het specifiek opnemen van het niveau van het bedrijf, simultaan met de bijbehorende ruimtelijke factoren, heeft een aantal voordelen. Ten eerste kan op die manier worden gecorrigeerd voor bedrijfsspecifieke kenmerken die samenhangen met het bedrijfspresteren (micro-microrelaties). Zo kan het belang van de regio zuiver worden vastgesteld. Concentreren grote bedrijven, die door schaalvoordelen productiever zijn, zich bijvoorbeeld in bepaalde regio's, dan komen de productiviteitsverschillen tussen regio's hier voort uit de ongelijke ruimtelijke verdeling van de bedrijven, en niet door lokale omstandigheden die hen beter laten functioneren. In dit zuivere en additionele effect van de regio zijn we in deze studie met name geïnteresseerd.

Ten tweede zijn bedrijfsspecifieke karakteristieken relevant, omdat deze mogelijk op een andere manier aan de ruimtelijke context zijn verbonden: niet alle bedrijven profiteren, maar alleen die bedrijven met specifieke kenmerken, zoals kleine bedrijven, jonge bedrijven of bedrijven in bepaalde sectoren. Dit verschijnsel wordt ook wel 'crosslevel-interactie' genoemd.[2] Zonder deze nuances is het (zowel beleidsmatig als wetenschappelijk) lastig om de relatie tussen het bedrijf en de regio effectief te bepalen. Kunnen we rekening houden met deze bedrijfspecifieke karakteristieken, dan kunnen we de rol van de regio zuiverder inschatten. Het is kortom belangrijk om een onderscheid te maken tussen zogenaamde contextuele effecten – ofwel het 'zuivere' effect van lokaal gebonden kennisexternaliteiten – en zogenaamde compositie-effecten – ofwel de effecten die voortkomen uit de samenstelling van bedrijfskenmerken in de regio. Hoofdstuk 2 gaat uitvoerig in op deze en andere voordelen van een multilevelanalysekader.

Met deze studie willen we conceptueel en empirisch bijdragen aan de vraag of en hoe ruimtelijk gebonden kennisexternaliteiten het functioneren en presteren van bedrijven beïnvloeden. De centrale vraagstelling is:

Hoe zijn ruimtelijk gebonden kennisbronnen wederzijds en simultaan verbonden aan economische groeiprocessen op zowel regionaal als bedrijfsniveau?

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2 Cross-levelinteractie definiëren we als het interactie-effect tussen de verschillende schaalniveaus (Hox 2002); in deze studie is dat het effect dat bepaalde ruimtelijke factoren anders doorwerken naar gelang de kenmerken van het bedrijf. Ter illustratie: het is te verwachten dat kleine bedrijven sterker profiteren van externe kennisbronnen dan grote bedrijven, aangezien deze laatste groep veel meer in staat is eigen kennisinvesteringen te doen (zie hoofdstuk 2 voor deze interactie-effecten).

Deze centrale vraag is in empirische zin uitgewerkt in de hoofdstukken 3 tot en met 7. Hoofdstuk 3 gaat over de ruimtelijke verschijningsvorm van de kenniseconomie: wat is de relatie tussen de diverse ruimtelijke patronen van kennis en de economische groei van regio's? Het gaat hierbij om een macro-macro-analyse (zie figuur 1.1), waarbij Nederlandse regio's (gemeenten) de eenheid van analyse zijn.

Ook in hoofdstuk 4 zijn de ruimtelijke patronen van kennis het vertrekpunt. Tegelijkertijd gaat het in dit hoofdstuk om de vraag of de overlevingskans en de groeipotentie van bedrijven op microniveau afhangen van deze ruimtelijke kennisfactoren (gecontroleerd voor relevante bedrijfskenmerken als grootte, leeftijd en sector[3]).

In hoofdstuk 5 en 6 staat de productiviteit van bedrijven centraal: zijn het alleen interne kennisbronnen die ertoe doen, of gaat het ook om de ruimtelijke context en daarbinnen aanwezige kennisexternaliteiten? Hierbij wordt specifiek rekening gehouden met zogenaamde 'crosslevel-interactie-effecten'.[4]

In hoofdstuk 7 zoomen we in op de nieuwe bedrijven.[5] Juist van nieuwe bedrijven wordt verwacht dat ze profiteren van externe kennisbronnen. Ze hebben immers zelf nog weinig aan eigen kennisinvesteringen kunnen doen en kiezen een niche gebruikmakend van nog niet-vercommercialiseerde kennis van andere bedrijven of universiteiten (de kennisspillovertheorie van ondernemerschap; Acs et al. 2004, Audretsch et al. 2006).

Hoofdstuk 8 sluit af met een samenvatting en enkele conclusies.

De ruimtelijke kenniseconomie is een complex patroon van verschillende dimensies

De kenniseconomie is verbonden aan een complex ruimtelijk patroon van kenniseconomische specialisaties. Dit patroon is afhankelijk van de verschillende aspecten die zijn verbonden aan het interpreteren van de kenniseconomie. In deze studie hanteren we een breed perspectief op de kenniseconomie, met acht indicatoren[6]: (1) opleidingsniveau, (2) communicatieve vaardigheden, (3) creatief kapitaal, (4) informatie- en communicatietechnologie (ICT), (5) onderzoek en ontwikkeling (Research and Development, R&D), (6) hightech- en mediumtech-bedrijven, (7) technologische innovatie en (8) niet-technologische innovatie. Deze acht indicatoren hebben verschillende ruimtelijke patronen. Sommige zijn sterk verbonden aan een stedelijke hiërarchie; dit type kennis concentreert zich nadrukkelijk in de grootste steden en agglomeraties. Dit geldt bijvoorbeeld voor het gemiddeld opleidingsniveau en het gebruik van ICT. Andere indicatoren, zoals R&D, hebben vooral te maken met de aanwezigheid van enkele grote bedrijven en instellingen. In Nederland is R&D veel minder geconcentreerd in de (grote) steden. De regio Eindhoven, met bedrijven als Philips en ASML, en de regio's Twente, Wageningen en Delft hebben de sterkste concentraties van R&D-intensieve activiteiten. Tot slot zijn bedrijven in de Randstad, uitwaaierend naar het oosten van het land, over het algemeen innovatiever dan bijvoorbeeld bedrijven in de periferie van Nederland. In deze regio's zijn bedrijven succesvoller in het op de markt brengen van nieuwe producten en diensten en het doorvoeren van bedrijfsinterne vernieuwingen.

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3 Hoofdstuk 4 hanteert een singlelevelmicro-analyse (OLS) en geen multilevelanalyse.

4 Hoofdstukken 5 en 6 hanteren een multilevelanalyse. Hoofdstuk 5 laat bovendien het voordeel zien van multilevelanalyses door de uitkomsten ook met singleleveluitkomsten (OLS) te vergelijken.

5 Hoofdstuk 7 hanteert een multilevelanalyse.

6 Zie hoofdstuk 3 voor een literatuuroverzicht, voor een definitie van het begrip kenniseconomie en de indicatoren, en voor figuren van de ruimtelijke patronen.

Met andere woorden: sterke kenniseconomische regio's laten zich niet éénduidig aanwijzen en meerdere indicatoren zijn daarbij van belang. Hoe breder de definitie van kenniseconomie, hoe meer regio's opvallen vanwege hun economische ontwikkelingspotentieel.

De bovengenoemde indicatoren vertonen een ruimtelijke overlap. Deze overlap wordt veroorzaakt doordat bedrijven zich op meerdere van deze indicatoren kenmerken (bedrijven met veel hoogopgeleide werknemers gebruiken over het algemeen veel ICT, bedrijven met veel R&D zijn vaak hightech-bedrijven). Anderzijds ontstaat de overlap doordat bedrijven die zich op bepaalde kenmerken onderscheiden, in ruimtelijk opzicht bij elkaar gaan zitten, ofwel: clusteren. Om onafhankelijke dimensies van de ruimtelijke kenniseconomie te typeren, is in hoofdstuk 3 een factoranalyse uitgevoerd. Deze mondt uit in drie onafhankelijke pijlers (factoren) van de kenniseconomie, te weten: (1) 'kenniswerkers' (een samenstelling van de indicatoren opleidingsniveau, ict-gebruik, en creatieve en communicatieve vaardigheden), (2) innovatie (een samenstelling van de twee innovatie indicatoren) en (3) R&D (een samenstelling van indicatoren voor 'hightech en mediumtech' en 'onderzoek en ontwikkeling'). Deze drie factoren vatten de ruimtelijke patronen van de acht indicatoren samen, waarbij zo min mogelijk overlap tussen de dimensies optreedt.

Een belangrijke eerste uitkomst van de factoranalyse is daarmee dat de regio's die zich specialiseren in 'kenniswerkers' (een kenmerk voor de aanwezigheid van veel menselijk kapitaal) over het algemeen niet de regio's zijn die tegelijkertijd gekenmerkt worden door hoge intensiteiten van 'R&D' en 'innovatie'. In de Nederlandse context heeft dit te maken met het onderscheid tussen industriële en dienstensectoren. Zakelijke diensten zijn sterker gebonden aan steden en agglomeraties dan industriële sectoren; de laatste bevinden zich nadrukkelijker aan de randen van agglomeraties en in de periferie van Nederland (zie hoofdstuk 3, of Raspe en Van Oort 2004 voor meer uitleg). Ook komt naar voren dat regio's met hoge kennisintensiteiten niet per definitie het meest innovatief zijn. Zo zijn R&D-investeringen niet noodzakelijkerwijs vereist om innovatief te kunnen zijn. Bedrijven kunnen 'kennis' ook inkopen of kopiëren van andere bedrijven. Ook leiden niet alle R&D-investeringen tot innovatief succes. Sterker nog: slechts een fractie van deze inspanning komt daadwerkelijk tot uitdrukking in een nieuw product of dienst. Daarnaast is ook niet-technologische vernieuwing in ons perspectief van belang. Bedrijven kunnen organisatorische vernieuwingen doorvoeren, bijvoorbeeld in productie*processen*, los van 'onderzoek en ontwikkeling'. Ook hier speelt het onderscheid tussen economische activiteiten in diensten en industrie een rol: industriële bedrijven doen veel meer aan R&D dan diensten, althans in de traditionele betekenis. Tot slot kan ook de arbeidsdeling van bedrijven zelf een rol spelen. Wat op een R&D-afdeling op een bepaalde locatie wordt 'bedacht', kan elders tot succes leiden. Zo zijn de onderzoeksactiviteiten van Philips gevestigd in de regio Eindhoven terwijl het hoofdkantoor in Amsterdam zit en veel productie (met daaraan verbonden werkgelegenheid) elders in de wereld plaatsvindt. In ruimtelijk opzicht kunnen 'R&D' en 'innovatie' dus relatief ontkoppeld zijn (zie hoofdstuk 3 voor de discrepanties tussen de ruimtelijke patronen).

Voor de drie pijlers of factoren van de kenniseconomie hebben we vervolgens gekeken naar hun relatie met economische groei (in werkgelegenheid en productiviteit). Hoofdstuk 3 gaat daar uitvoerig op in. Op die plekken waar kennis zich ruimtelijk concentreert, blijken zich inderdaad gunstige economische ontwikkelingen voor te doen: met name voor de factoren 'kenniswerkers' en 'innovatie' is dit het geval. Hoge intensiteiten op het gebied van de technologische R&D-factor hebben een minder directe regionale uitstraling. Dit betekent dat niet alleen onderzoek en ontwikkeling maar juist ook 'zachtere factoren' bepalend zijn voor het succes in de kenniseconomie; denk aan slim managen en innovatief organiseren.

De regio maakt uit

Het multilevelvraagstuk dat we in dit proefschrift onderzoeken, betreft het effect van de ruimtelijk gebonden kennisexternaliteiten, ofwel: presteren bedrijven in regio's met veel kennisexternaliteiten beter dan bedrijven in regio's met minder kennisexternaliteiten? Regio's met veel kennisbronnen zijn inderdaad in het voordeel, zo blijkt uit hoofdstuk 3: ze ontwikkelen zich in economisch opzicht beter dan regio's met minder kennisbronnen. De vraag is echter of dit verband ook houdbaar is op het niveau van het bedrijf. Dit effect is onderzocht met een multilevelanalyse, Een eerste stap daarbij is om te bepalen of de regio er inderdaad toe doet, wanneer we simultaan bedrijfsspecifieke kenmerken meenemen in de analyse. In hoofdstuk 2 is aangeven dat multilevel analyse (en de decompositie van de variantie over de verschillende hiërarchische schaalniveaus die daarmee mogelijk is) een goede methode om het relatieve belang van de regio te kunnen bepalen. Het belang van de regio is af te leiden uit de zogenaamde *intraclass correlation*[7].

Een belangrijke uitkomst van de intraclass correlation is dat ongeveer 2,5 procent van de productiviteit en ongeveer 1 procent van de werkgelegenheidsgroei kan worden toegerekend aan de locatie van een bedrijf. Ruimtelijk gebonden externaliteiten lijken dus wel degelijk te bestaan, hoewel de heterogeniteit op het niveau van het bedrijf dominant is bij het bepalen van de prestaties van bedrijven. Dat het gaat om wat er 'in het bedrijf gebeurt', is op zich niet verwonderlijk. Zelfs in een relatief klein land als Nederland (met een uitzonderlijke policentrische stedelijke structuur en een relatieve uniforme verdeling van culturele, woningmarkt en stedelijk-economische kwaliteiten) maken locatieverschillen daadwerkelijk uit voor bedrijfsprestaties. Met andere woorden: de locatie van een bedrijf heeft een eigen economische waarde.

Kennisexternaliteiten bepalen de prestatie van bedrijven

Het gaat er niet alleen om te bepalen wat de impact van de regio is. Daarnaast is het van belang te duiden wat de factoren zijn waardoor bedrijven in een regio beter presteren. Tabel 8.1 vat de uitkomsten uit de empirische hoofdstukken samen.

Innovatie

Bedrijven presteren beter wanneer zich in hun directe omgeving veel succesvolle innovatoren bevinden. Dat wil zeggen dat clusters (ruimtelijke concentraties) van bedrijven die succesvol nieuwe producten en diensten op de markt brengen of organisatorisch vernieuwen (beiden zijn kennisexternaliteiten) een spillovereffect met zich meebrengen, waardoor individuele bedrijven beter presteren (productiever zijn en harder groeien). Deze uitkomsten passen in een onderzoekslijn van territoriale innovatiesystemen: de verspreiding van kennis in innovatieve regio's leidt ertoe dat bedrijven binnen die regio's succesvoller zijn in hun prestaties en in hun toekomstig innovatief succes (Breschi et al. 1998, Malerba en Orsenigo 1997, Cooke 2001 en Moulaert en Sekia 2003).

Enerzijds draagt de regionale concentratie van innovatieve bedrijven positief bij aan het presteren van bedrijven, ook voor nieuwe bedrijven. Anderzijds functioneert de regio ook als een selectiemechanisme: ze beïnvloedt de overlevingskans van deze nieuwe bedrijven in eerste instantie negatief. Nieuwe toetreders die niet in staat zijn zich snel aan te passen aan de druk in hoog-

7 Zie hoofdstuk 2 voor een beschrijving van de intraclass correlation en de afleiding daarvan in formules.

innovatieve regio's, worden erdoor uit de markt gedrukt. Nieuwe bedrijven die overleven, profiteren in tweede instantie wel van dit competitieve milieu.

R&D
Hoge regionale R&D-intensiteiten zijn in het algemeen veel minder nadrukkelijk van invloed op de bedrijfsprestaties. Technologische externaliteiten blijken met name van belang te zijn voor bestaande bedrijven in de zakelijke diensten. Een mogelijke verklaring hiervoor is dat binnen de zakelijke diensten 'onderzoeks- en ontwikkelingsactiviteiten' zijn geclassificeerd. Juist die activiteiten zijn gevoelig voor externe R&D-bronnen (Audretsch en Dohse 2007, Simmie 2002, Audretsch 2003 en Feldman 1994). Uit de analyses van hoofdstuk 5 blijkt dat R&D-intensieve bedrijven inderdaad gevoelig zijn voor hun regionale context (zie voetnoot 28) en uit de analyses van hoofdstuk 7 blijkt dat juist nieuwe R&D-intensieve bedrijven profiteren van externaliteiten (de aanwezigheid van een universiteit in dit geval). Tot slot blijkt een hoge regionale R&D-intensiteit ook de overlevingskansen van nieuwe bedrijven in de zakelijke diensten positief te beïnvloeden. Hoewel indirect, past deze bevinding in de lijn van denken van de 'kennisspillovertheorie van ondernemerschap'.

Menselijk kapitaal
Bestaande bedrijven in de zakelijke dienstverlening ondervinden een positief effect van aan de dimensie 'menselijk kapitaal' gerelateerde aspecten (zogenaamde kenniswerkers, bestaande uit regio's met een hoge intensiteit op opleiding, ict-gebruik, creatieve en communicatief kapitaal). Deze bevinding is in lijn met onderzoeken van Muller en Doloreaux (2009), Glaeser en Kohlhase (2004) en Kolko (2000). Met name bedrijven in de zakelijke diensten profiteren van een concentratie van hoogopgeleide mensen (arbeidspool), doordat de kosten van arbeidsmigratie nog steeds hoog zijn en veel kennisintensieve diensten in hun bedrijfsprocesssen gebruiken maken van face-to-face-contacten (Storper en Vanables 2004).

Opmerkelijk genoeg heeft de dimensie 'menselijk kapitaal' ook een negatief effect op de overleving en groei van zowel bestaande als nieuwe bedrijven. Zoals in hoofdstuk 3 is aangegeven, hebben regio's met een sterke concentratie van menselijk kapitaal een sterk stedelijk karakter. De negatieve relatie kan dus voor een deel zijn toe te schrijven aan de competitie tussen bedrijven om de vitale (kennis) bronnen in steden. Dit is in lijn met de literatuur over de 'geografie van kansen'. Deze literatuur (zie Sorenson and Audia 2000, Stuart en Sorenson 2003) duidt juist deze ruimtelijke concurrentie. Factoren die bijvoorbeeld de oprichting van nieuwe bedrijven stimuleren, verschillen in die optiek van de factoren die de bedrijfsprestaties na oprichting bevorderen. Nieuwe bedrijven in regio's met een hoge dichtheid kunnen profiteren van ruimtelijke kennisexternaliteiten, maar ze kunnen ook nadelen ervaren van de concurrentie die samengaat met de sterke concentratie van nabije concurrenten (zowel bestaande als andere nieuwe bedrijven). Dit type effecten is in ons onderzoek niet direct opgenomen, al zijn ze toekomstig onderzoek zeker waard.

De interactie tussen bedrijfskenmerken en de regio
Mogelijk is het regio-effect niet relevant voor alle bedrijven, maar alleen voor bedrijven met specifieke kenmerken. Uit een analyse van de zogenaamde cross-levelinteractie-effecten blijkt dat het vooral kleine bedrijven zijn die profiteren van externe kennisbronnen, dit in tegenstelling tot grote bedrijven. Waar grote(re) bedrijven over het algemeen over een grotere interne kennisbasis beschikken, hebben klein(ere) bedrijven juist kennis nodig van buiten de 'muren' van het bedrijf.

Daarnaast komt uit empirische studies naar voren dat het spilloverpotentieel sterk sectorgebonden is. 'Slechts' enkele economische activiteiten zijn gevoelig voor kennisexternaliteiten. We hebben indicaties dat dit met name geldt voor nieuwe bedrijven in de sector 'onderzoek en ontwikkeling'; de aanwezigheid van een universiteit heeft bijvoorbeeld een positieve invloed op hun 'groei-na-oprichting'.[8] Deze bevinding is in lijn met de 'kennisspillovertheorie van ondernemerschap', en met onderzoek van Acs et al. (2004). Ook bedrijven in de financiële dienstverlening profiteren van ruimtelijk gebonden kennisexternaliteiten, met name de aanwezigheid van veel 'kenniswerkers'. Nabijheid tot een arbeidspool van hoogopgeleide, veel ict-gebruikende, communicatieve en creatieve arbeidskrachten heeft voor dit type bedrijven een positief effect op hun ontwikkeling.

De empirische hoofdstukken uit dit proefschrift leren ons dat het gebruik van de multilevelanalyse een toegevoegde waarde heeft bij het bepalen van het relatieve belang van de regio en bij het bepalen van 'wat het in de regio' is dat (sommige) bedrijven beter laat presteren. We hebben daarmee meer grip op de heterogeniteit op het niveau van het bedrijf en de regio, en bij de interactie daartussen.

Terug naar de 'de regio' en regionaaleconomische ontwikkeling

We definieerden het vraagstuk van dit proefschrift als een intrinsiek multilevelprobleem. Met het empirische onderzoek wilden we het bedrijf (microniveau) betrekken in het economisch-geografische vraagstuk van kennisexternaliteiten (op macro niveau). Naar analogie van Coleman (1986) gaat het hierbij met name om de toets of ruimtelijk gebonden kennisbronnen tegelijk met bedrijfsspecifieke kenmerken te verbinden zijn aan economische prestatieprocessen op het bedrijfsniveau (zie figuur 1.1). Dit onderzoeksprobleem is echter ingebed in een analyseveld waarin regio's en regionale ontwikkeling centraal staan. De vraag die nu nog rest, is wat onze bevindingen betekenen voor regionale-ontwikkelingsvraagstukken.

Het belang van microprocessen (bedrijf) voor het verklaren van macro-uitkomsten (regio) bevindt zich typisch in het domein van de sociale wetenschappen (Wippler en Linderberg 1987, Coleman 1990). Deze onderzoeksdiscipline heeft een sterke interesse in vragen over hoe het individueel gedrag zich vertaalt in collectieve uitkomsten. Ze leert ons dat er bij micro-macro-interacties ten minste vier typen 'transformatiemechanismen' kunnen optreden (Groenewegen 1997): (1) aggregatie, waarbij individueel gedrag wordt getransformeerd tot een collectieve uitkomst door mathematisch 'op te tellen', (2) partiële definitie (of definitie door conventie), waarbij het bereiken van een bepaald niveau representatief wordt geacht voor de collectieve uitkomst, (3) institutionele regels, waarbij de transformatie is ingegeven door een 'arbitraire' regel, zoals een meerderheidsregel, en (4) speltheorie en simulatie, waarbij naar analogie van een 'spel met veronderstelde regels' een collectieve uitkomst wordt gesimuleerd.

Bij de vraag hoe bedrijfsprocessen en -resultaten de ontwikkeling op regionaal niveau beïnvloeden, speelt met name transformatiemechanisme (1) een rol. De prestaties van bedrijven in een regio tellen op tot een collectief effect op regionaal niveau. Bestuderen we externe effecten via een multilevelanalysekader waarbij impliciet wordt gecontroleerd voor compositie-effecten, dan is het

8 In hoofdstuk 5 vinden we ook een zogenaamd significant 'random slope'-effect voor R&D-intensieve bedrijven op productiviteit. Dit betekent dat juist deze bedrijven gevoelig zijn voor hun regionale context.

effect van externaliteiten op bedrijfsniveau tegelijkertijd het effect op geaggregeerd niveau. De bij kennisexternaliteiten zo relevante synergie-effecten (de som van wat er in de regio is, is meer dan de delen) zijn hierbij immers al in ogenschouw genomen. Dezelfde redenering geldt echter niet andersom. In goed presterende regio's bevinden zich zeker ook slecht presterende bedrijven, waarbij het zelfs zo kan zijn dat de goede regionale prestaties worden bepaald door 'slechts' enkele zeer goed presterende bedrijven. Om die reden pleiten we ervoor de heterogeniteit op het niveau van bedrijven op te nemen en de cross-levelinteractie-effecten die bedrijfsspecifieke karakteristieken hebben met de ruimtelijke omgeving. Veel sociaalwetenschappelijke vraagstukken zijn van een andere orde en hebben veel nadrukkelijker te maken met transformatiemechanismes (2)-(4). In het kort concluderen we dat transformatie door aggregatie, hoewel een uitzondering in studies in de sociale wetenschappen (Groenewegen 1992), toepasbaar is op ons analysekader.

Toch gaat het bij prestaties van een verzameling bedrijven niet om een 'simpele' aggregatie naar regionaal niveau. Bij statische aggregatie wordt immers voorbijgegaan aan de bedrijfsdemografie in de regio. In regio's zijn er niet alleen bestaande bedrijven die al dan niet overleven, groeien en presteren, maar spelen ook de toetreding van nieuwe bedrijven en saldi van migratiegedrag van bedrijven een rol. Deze twee endogene processen (oprichtingen en verhuizingen) hebben een directe relatie met regionaal-economische ontwikkelingen. Beide zijn drijvende krachten achter de prestaties van een regio en worden sterk bepaald door ruimtelijke selectie en sortering (Baldwin and Okubo 2006, Knoben 2008). Zo geldt bijvoorbeeld dat de meest efficiënte (productieve) bedrijven zich ook als eerste (kunnen) ontwikkelen en als eerste (kunnen) migreren naar regio's waar veel kennisbronnen aanwezig zijn. Aan de andere kant stellen Comes en Duranton (2006) dat juist door het bestaan van agglomeratie-effecten (bijvoorbeeld arbeidsmarktpoolvoordelen) bedrijven ook strategische beslissingen nemen vanuit overwegingen die te maken hebben met de kans dat hun kennis(werkers) mogelijk naar andere bedrijven vertrekken. Ook om die reden is het fundamenteel om bedrijfsspecifieke karakteristieken op te nemen in regionale analyses.

Het is dus belangrijk om een onderscheid te maken in statische en dynamische interpretatie van onze analyses. De empirische bijdrage van ons onderzoek is hoofdzakelijk statisch: we houden geen rekening met het feit dat het presteren van bedrijven (en de geaggregeerde variant daarvan) ook van invloed is op het gedrag van bedrijven (de bedrijfsdemografie) in een volgende periode. Dit meer dynamische (evolutionaire) perspectief kan worden ontwikkeld door te focussen op veranderende ruimtelijke patronen, resulterend uit de oprichting van nieuwe bedrijven, de overleving en groei van bedrijven en de migratie van bedrijven tussen regio's (Frenken en Boschma 2007). In een dergelijk dynamisch kader noemen Maskell en Malberg (2007) een interessante ontwikkelingslijn, namelijk het inzicht om additioneel op de microprocessen ook hogereordeprocessen op het niveau van het cluster of de regio op te nemen in het onderzoek. Bijvoorbeeld de creatie van ondersteunende instituties, aanjagers van lokale cultuur en ook zaken die te maken hebben met regiomarkering (het op de kaart zetten van een regio door economische accenten te plaatsen). Die zaken kunnen de regionale kenniseconomische basis versterken en mogelijk veranderingen in de toekomstige regionale ontwikkeling bewerkstelligen. Hier past een ambitieuze onderzoeksagenda die de causale relaties tussen 'instituties en economische groei' als centraal thema heeft (Glaeser et al. 2004, Bathelt 2006).

Daarnaast zien we ons analysekader als het vertrekpunt van verdergaande statistische modellering voor de complexe relatie tussen bedrijf en omgeving. Bedrijven kunnen namelijk onderdeel zijn van meerdere hogereordeclassificaties, op een manier dat een strikte hiërarchische benadering tussen schaalniveaus niet toereikend is. Dergelijke modellen staan bekend als 'multiple membership'-multilevelmodellen (Browne et al. 2001, Fielding en Goldstein 2006). Bedrijven kunnen bijvoorbeeld niet alleen hiërarchisch genest zijn in een regio, maar ze kunnen tevens onderdeel zijn van 'waardeketens', institutionele of sectorgerelateerde netwerken, enzovoort. Dergelijke verbanden zijn veelal niet ruimtelijk, en bijvoorbeeld nationaal of internationaal georganiseerd. In het kort geldt dat bedrijven kunnen profiteren van meer externaliteiten dan alleen ruimtelijke. Meerdere hogereordeclassificaties kunnen simultaan in een multilevelstructuur worden gemodelleerd, waarbij niet alleen de ruimtelijke inbedding ook andersoortige 'lidmaatschappen' worden meegenomen. Dit type onderzoek valt buiten het bestek van dit proefschrift. Wel verdient het aanbeveling deze potentie nader uit te werken bij toekomstig onderzoek.

Tot slot

De aanbevelingen voor toekomstig onderzoek in ogenschouw nemend concluderen we dat het in dit proefschrift gepresenteerde onderzoek in zowel de conceptuele als empirische hoofdstukken enerzijds bijdraagt aan een betere begrip van de relaties tussen kennis die zich regionaal concentreert en anderzijds aan een beter begrip van het presteren van zowel bedrijven als regio's. Door de gekozen multilevelbenadering zijn we in staat om het belang van de regio te bepalen en te ontleden in 'wat het in de regio' is dat bedrijf beter doet presteren.

Curriculum Vitae

Otto Raspe was born on November 15th 1973 in Leek (Groningen), the Netherlands. He studied Economics at Tilburg University (1992-1997). After his graduation he worked as a researcher/consultant at The Netherlands Organization for Applied Scientific Research (TNO, Delft), where he advised on the topics of (spatial) economic development, the impact of spatial investments (impact analysis, cost-benefit analysis), industry studies and (regional) economic benchmarks. Since mid 2002 he works as senior researcher at The Netherlands Environmental Assessment Agency (PBL, the former Netherlands Institute for Spatial Research, RPB), in The Hague. Here his focus is on the (impact of the rise of the) knowledge economy, innovation, firm networks, clusters, entrepreneurship and neighborhood economics. Otto Raspe has published several articles in the field of regional science and economics in national and international journals and often gives lectures on these topics.