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Technological competencies and firm performance: Analyzing the importance of internal and external competencies

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ABSTRACT

In this paper, we analyze the relationship between technological competencies (TC) and firm performance. Theoretically, the importance of TC is well established and widely accepted. Therefore, it is surprising that a number of empirical studies have been unable to confirm a substantial positive relationship between TC and firm performance. We identify two major reasons for this: [i] affected by the availability and choice of indicators existing studies are often biased towards large firms; and [ii] they frequently do not consider both internal and potential access to firm-external TC. This paper discusses conceptually the interplay between firm-internal and firm-external TC as well as the mediating effect of firm size. These relationships are then analyzed empirically using Swedish micro data on 15,682 firms in 290 Swedish municipalities. Novel indicators based on occupational statistics are combined with measures of time-distance accessibility to study internal and external TC. The results provide evidence for a positive relationship between firm growth and TC. In particular, the combination of firm-internal and firm-external competencies seems to be conducive for growth. Lastly, our study suggests that firm size is an important factor to further our understanding about these relationships. Based on this we identify a number of future research questions to be addressed.

JEL Code: L25, O18, O30

Keywords: technological competencies; firm performance; accessibility; knowledge; innovation; geography

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Abstract

In this paper, we analyze the relationship between technological competencies (TC) and firm performance. Theoretically, the importance of TC is well established and widely accepted. Therefore, it is surprising that a number of empirical studies have been unable to confirm a substantial positive relationship between TC and firm performance. We identify two major reasons for this: [i] affected by the availability and choice of indicators existing studies are often biased towards large firms; and [ii] they frequently do not consider both internal and potential access to firm-external TC. This paper discusses conceptually the interplay between firm-internal and firm-external TC as well as the mediating effect of firm size. These relationships are then analyzed empirically using Swedish micro data on 15,682 firms in 290 Swedish municipalities. Novel indicators based on occupational statistics are combined with measures of time-distance accessibility to study internal and external TC. The results provide evidence for a positive relationship between firm growth and TC. In particular, the combination of firm-internal and firm-external competencies seems to be conducive for growth. Lastly, our study suggests that firm size is an important factor to further our understanding about these relationships. Based on this we identify a number of future research questions to be addressed.

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1 Introduction

A firm's competitive performance is based on its internal resource constellation, coupled with accessible external resources, and its ability to apply these resources productively (Barney, 1991; Prahalad and Hamel, 1990; Wernerfelt, 1984). In this context, knowledge, and technological knowledge in particular, is of special importance (Conner and Prahalad, 1996; De Carolis and Deeds, 1999; McEvily et al., 2004). Knowledge-based explanations pivot on the idea that firms with access to valuable knowledge that is scarce, difficult to imitate and substitute will gain a sustainable advantage ultimately resulting in higher performance and growth (Barney, 1991; Peteraf, 1993; Prahalad and Hamel, 1990). These knowledge-based explanations relate to the concept of technological competencies (TC). While there are different definitions of TC (for a comparison, see De Carolis, 2003), we follow the perhaps most common one according to which TC is described as the technological knowledge and skills embodied in people (Hall, 1993; Leonard-Barton, 1995; Richardson, 1972). The aim of this paper is to investigate the importance of both firm-internal and potential access to firm-external TC for firm performance.

The relationship between TC and firm performance has been widely studied (De Carolis, 2003; Franko, 1989; Geroski et al., 1993; Griliches, 1981; Jaffe, 1986; Lee, 2010; Pakes, 1985). Despite the widespread agreement on the importance of TC for performance, researchers have been unable to consistently find empirical support for a positive relationship between the two (Coombs and Bierly, 2006). At least two reasons for this can be identified. One reason is the availability and choice of indicators used for measuring TC. It has been argued that neither R&D expenditures nor the number of patents (i.e. the two most frequently used indicators) are valid indicators of TC (Coombs and Bierly, 2006; Jacobsson et al., 1996).

Moreover, these indicators are biased towards large firms leading to a certain ignorance of the implications of firm size. We argue in this paper, however, that firm size is an important factor for furthering our understanding of the relationship between TC and firm performance. Another shortcoming of previous studies is that they frequently do not capture both firm-internal and firm-external TC despite the well-grounded theoretical argument that the two are inherently related as the extant debate on absorptive capacity shows, going back to Cohen and Levinthal's (1990) seminal contribution.

In order to address these shortcomings, we discuss conceptually the interplay between firm internal and external TC as well as the mediating effect of firm size. Then, we introduce a novel way to measure both internal and external TC. TC, in our study, is represented by individuals in occupations that imply a high level of TC. Examples of such occupations are science professionals, R&D managers, or corporate managers with scientific training. We argue that the use of occupational data has distinct advantages over R&D and patent data. As regards firm-internal TC, we account for the relative share of individual with a high-level of TC in a firm's total number of staff. Concerning firm-external TC, we introduce the concept of accessibility, which is based on the time-distance between a firm's location and the locations of firm-external TC. We argue that, all other things equal, the potential access to firm-external TC increases with geographic proximity to such sources, i.e. if individuals with a high level of TC are located close by. We analyze the relationships between firm performance and internal as well as external TC using a dataset from Statistics Sweden (the government agency for statistics) comprising 15.682 firms in 290 Swedish municipalities.

The paper is structured as follows. The second chapter addresses the theoretical and conceptual background, in which we, firstly, discuss the link between TC and firm performance differentiating in internal and external TC. Then, we elaborate on the strength and weaknesses associated with different indicators of TC in previous empirical studies before we introduce the concept of accessibility to firm-external TC. The third chapter presents our empirical study. We provide detailed information about the dependent and independent variables, describe the data sources and the empirical model and present the results. In chapter four, we discuss our results and conclusions as well as avenues for future research.

2 Theoretical and conceptual background

2.1 Technological competencies and firm performance

A firm's competitive advantage is largely based on its ability to generate and utilize knowledge and skills in general and technological competencies (TC) in particular (e.g. De Carolis, 2003; Franko, 1989; Lee, 2010). An important reason for this is that TC increases the firm's ability to discover and exploit opportunities – i.e. the firm's innovative capacity (Wiklund and Shepherd, 2003). Most innovations build either on incremental enhancement and adaptation, or on the radical new application of knowledge. Therefore, a firm's TC, together with accessible external TC, plays a central role for its competitiveness (Cantwell and Fai, 1999; Cohen and Levinthal, 1990). This is particularly the case for technology-based firms, i.e. firms with a high level of TC that compete on the basis of their technological advantage (De Carolis, 2003; Franko, 1989).

As a result of the cumulative nature of learning, TC is built over time in a highly complex and path dependent process (Patel and Pavitt, 1997). Consequently, while an increase in R&D expenditures can lead to the accumulation of TC over time, instantaneous changes in the TC of a firm are highly unusual. Accordingly, the profile of corporate TC tends to be stable over relatively long time periods (Cantwell and Fai, 1999; Dierickx and Cool, 1989; Patel and Pavitt, 1997), making competitive advantages derived from TC difficult to imitate by competitors and thus sustainable. This also implies, however, that a firm's future TC is to a large extent dependent on its historically developed TC (Dosi, 1988).

A number of empirical studies have confirmed the positive relationship between firm performance and indicators of TC (notably R&D expenditures and patents). For example Franko (1989) finds that differences in R&D expenditures is the perhaps most important explanation for performance variations between large multinational corporations. Pakes *et al.* (1985), Griliches (1981), and Deng *et al.* (1999) find positive relationships between R&D expenditures and patents and firm performance in terms of stock market value. De Carolis (2003) find a positive relationship between patents and return on assets, but surprisingly a negative relationship to market-to-book value. In a study of Taiwanese electronics firms Yang and Huang (2005) find that R&D expenditures are positively related to employment and sales growth. Investigating a sample of small start-up firms in Korea, Lee *et al.* (2001) conclude that TC, represented by the number of patents and quality control capabilities, are positively related to sales growth. García-Manjón and Romero-Merino (2012) investigate the effects of corporate R&D intensity in 754 top European R&D spending firms and find a positive relationship with sales growth.

While there is substantial support for the relationship between TC and firm performance, the results are, however, not always as substantial and direct as could be expected from the theoretical literature (Coombs and Bierly, 2006; see e.g. De Carolis, 2003; Geroski et al., 1993; Pakes, 1985). This reflects a need for further studies of the effects of TC on firm performance, using alternative empirical indicators and data. As will be elaborated in the next chapter, the predominant use of indicators such as R&D expenditures and patents overestimates the TC of large firms and firms in certain high-tech sectors while underestimates the TC of other firms (Coombs and Bierly, 2006; Jacobsson et al., 1996). Also, existing studies frequently focus on specific sectors or type of firms rather than an economy-wide sample. For these reasons, there is a lack of more general empirical evidence about the relationship between the level of firms' TC and firm performance. The first step, therefore, is to test our basic assumption using novel data and indicators:

H1: Firms with a high level of TC grow faster than firms with a low level of TC.

Most studies of firm-level TC focus only on those competencies possessed by the firm, i.e. firm-internal TC. At the same time, there is wide agreement that a firm's competitive ability is greatly affected by its access and ability to exploit resources from its environment (Cohen and Levinthal, 1990; Gulati, 2007; Zaheer and Bell, 2005). Firm-external resources provide opportunities for faster access to a wider range of resources as compared to developing these internally, while at the same time increasing the reach of the firms' current resources (Sanchez and Heene, 1997). Furthermore, the potential advantages from this are particularly great when such external resources are complementary or superior to the firm's internal resource stock (Langlois, 1992; Teece, 1986; Teece et al., 1997). Similarly, Harrison (2001) argues that complementary resources in other firms can create synergies when combined with a firms internal resources.

The literature on complementary firm-external resources has largely been developed in relation to strategies for synergy creation in strategic alliances, joint ventures, and mergers and acquisitions (Gulati, 2007; Harrison et al., 2001; Lavie, 2006). However, access to external knowledge resources takes place not only, and arguably not even primarily, in the specific confines of formal alliances or through mergers and acquisitions. Knowledge is also shared in non-formalized settings and informal networks when people meet and interact. Furthermore, the propensity to enter into formal collaborations, alliances, or joint ventures is greatly influenced by such informal networks (Gulati, 2007; Owen-Smith and Powell, 2004). Based on the assumed importance of firm-external resources for firms' performance, our second hypothesis is that:

H2: Firms with high access to firm-external TC grow faster than firms with low access to firm-external TC.

Much of the literature on firm-external resources, particularly the above-mentioned literature on strategic alliances, joint ventures, and mergers and acquisitions, is focused on large corporations. However, it is widely acknowledged that, because of their limited in-house resources and capabilities, the potential benefits from accessing external resources is even greater for small firms (Baum et al., 2000; Zeng et al., 2010). In addition to this, it has been repeatedly shown that firm performance in general is closely related to firm size and age. This is conceptualized in terms of liabilities of smallness and newness (cf. Freeman et al., 1983; Stinchcombe, 1965). Liabilities of smallness originate in impediments when it comes to raising capital and resources, meeting governmental requirements, and competing for labor with larger organizations (Aldrich and Auster, 1986). The latter of these is of particular interest in our study. It is argued that small firms have difficulties to compete for skilled labor and thus generate sufficient in-house TC. This is relevant both for the ability to generate new knowledge in-house as well as for the absorptive capacity to source knowledge externally. An additional liability affecting small firms is related to managerial weaknesses. Larger organizations typically have better-trained and more experienced managers (Brüderl and Schüssler, 1990) affecting their ability to use and deploy internal TC as well as access external TC. Furthermore, it is argued that the limited in-house TC of smaller firms circumscribes their ability to conduct own R&D (Barnett and Storey, 2000; Hausman, 2005; Kaufmann and Tödtling, 2002). Overall, therefore, we have strong reasons to assume that the relationship between both internal and external TC and firm growth depends on firm size.

H3a: The relationship between the level of TC and firm growth depends on firm size.

H3b: The relationship between access to firm-external TC and firm growth depends on firm size.

Most importantly, however, interdependencies exist between the level of internal TC and a firm's access to external TC. A firm's internal competencies and skills greatly influence its choice of collaboration partners (cf. Neffke and Henning, 2013), its attractiveness as a collaboration partner for other firms (Ter Wal and Boschma, 2011), as well as its capacity to absorb knowledge from external sources (Cohen and Levinthal, 1990). The concept of absorptive capacity is based on the idea that firms require a certain level of similar or related knowledge to be able to appropriate and ultimately benefit from external knowledge. However, a too homogenous internal knowledge base reduces the ability of an organization to absorb external knowledge (Cohen and Levinthal, 1990), which speaks in favor of a relatively broad definition of TC. It is argued that firms with a high level of internal TC are expected to have a higher absorptive capacity and, thus, to benefit more from access to firm-external TC. The combination of a high level of firm-internal TC and a high access to firm-external TC should, therefore, be particularly conducive for firm performance. On the other hand, this relationship is not self-evident because firms may, to some extent, substitute firm-internal TC with firm-external TC. Such a substitution should be most feasible for firms that have a high access to firm-external TC. Hence, the relationship between firm performance and the combination of high firm-internal and high potential access to firm-external TC is not necessarily positive, especially if substitution of TC is an important factor. Therefore, we test the following hypothesis:

H4a: Firms that combine a high level of firm-internal TC and a high access to firm-external TC grow faster than other firms.

Assuming that firm-internal and firm-external TC complement each other, smaller firms are assumed to benefit most from the combination of a high level of TC and a high accessibility to firm-external TC. The reason is that large firms with a high TI should be less dependent on complementary firm-external TC. Hence, the arguments leading to hypotheses 3a and 3b are assumed to amplify for the combination of internal and external TC leading to the following hypothesis:

H4b: The relationship between firm growth and the combination of internal and external TC is stronger for firms of smaller size as compared to firms of larger size.

2.2 The concept of technological competencies in empirical studies

In empirical research, TC is usually measured by input or output indicators. The most common input indicator is R&D expenditures while the most frequently used output indicators are number of patents and number of scientific publications (Coombs and Bierly, 2006). R&D and patents are the by far most frequently used (De Carolis, 2003; García-Manjón and Romero-Merino, 2012; Lee, 2010). These indicators have distinctive strengths and weaknesses.

Patents are seen as an indicator of the existence of valuable technological knowledge within a firm – i.e. its TC (De Carolis, 2003). While patent data is relatively easily accessible and provides quite detailed information on assumed outputs of inventive activity (Griliches, 1990; Pakes, 1985; Patel and Pavitt, 1997), it also has a number of weaknesses. One major weakness is that the propensity to patent varies significantly by industry, firm size and patenting strategy (Brouwer and Kleinknecht, 1999; Jacobsson et al., 1996). This makes patent data particularly problematic in multi-industry studies. The varying propensity to patent is largely based on the fact that not all output of technological development is patentable (Scherer, 1983). Furthermore, the propensity to apply for patents is greatly influenced by the patenting strategy of the firm and within the industry. In some industries strategic patenting, i.e. patents taken 'around' the primary patent in order to block competitors, is more common than in other industries (Coombs and Bierly, 2006). Patent frequency also differs between countries, reducing the ability for international comparisons (Jacobsson et al., 1996). Lastly, a historical weakness with patent data, which has been addressed at least partially by the inclusions of patent quality metrics, is that patents differ greatly in terms of their technological and economic significance (Griliches, 1990; Pakes, 1985).

The most common input measurement of TC is corporate R&D expenditures. While R&D expenditures correlate highly with the number of patents (according to Griliches, 1990 a median R-square of 0.9 across firms and industries), R&D data captures not only the codified knowledge reflected in patent applications (Griliches, 1990), but can also be seen as an indicator of tacit or uncodified knowledge (Patel and Pavitt, 1997). However, the use of R&D data also has a number of shortcomings. Firstly, not all R&D is reported to the statistics bureaus. This results in a substantial and systematic underestimation of the technological activities of smaller firms that lack formal R&D departments (Brouwer and Kleinknecht, 1999). Secondly, this measure is based on the assumption that R&D expenditures lead to the production of TC. This means that, like patent-data, R&D expenditures is an indirect measure of TC.

In an analysis of Swedish data, Jacobsson et al. (1996) find that the top 25 R&D spenders account for 80 percent of all business R&D in the country. However, these firms only employ about 30 percent of the engineers and natural scientists. Interestingly, they also find that R&D statistics are not as closely correlated to patents as could be expected. The top 25 R&D firms account for only 37 percent of the total number of patents granted in the US (Patel and Pavitt, 1990 show similar results using data on UK firms). The use of R&D indicators is thus highly biased towards the largest firms in the economy and leads to an underestimation of the technological activity of small- and medium-sized firms. Based on this, Jacobsson et al. (1996) promote the use of educational statistics to measure TC. They argue that educational data captures scientific and technological activities that do not lead to patents or scientific references, as well as technological activities that are not classified as formal R&D in the statistics. Educational data has the advantage of being a more direct indicator for the knowledge embodied in people than R&D and patent data. However, problems arise also with educational statistics. One important disadvantage is the failure to capture on-the-job training or a shift in specialization of individuals whose university training may be largely outdated. While educational statistics indicate the training of an individual at one point in time, it is an unreliable indicator for the work performed at present.

In this paper we, therefore, use occupational statistics as indicator of TC. Occupational data has the advantages of educational statistics but not its weaknesses of measuring historical and possibly outdated 'values'. The occupational data used in this study is based on a classification along two dimensions: [1] the type of work (i.e. the set of tasks that are performed by an employee), and [2] the skills required to perform the work. The data thus contains an implicit educational dimension, i.e. the level of education *usually* required to perform the tasks. The use of occupational data has the advantage, as compared to educational statistics, that it also considers the type of work that an individual is actually conducting. This means that occupational data has a greater potential to capture on-the-job-training and shifts in specialization of individuals since their time of graduation. Compared to R&D and patent data, occupational statistics is less biased towards larger firms and specific patent intensive sectors. With occupational statistics it is possible to relatively accurately identify highly skilled scientists and engineers who perform tasks of a scientific and technological nature. Such individuals are presumed to be the main carriers of firms' TC. This means that occupational data is a more direct measure of TC than R&D and patents.

2.3 Access to firm-external technological competencies

As discussed previously, the ability to identify, access and utilize firm-external TC depends on the firm's absorptive capacity and its internal TC in particular. In addition, however, the ability to access external TC is at least partly contingent on space. Research in economic geography and regional economics provides compelling evidence to this effect (e.g. Asheim and Isaksen, 2002; Breschi and Lissoni, 2001; Gertler and Levitte, 2005; Glaeser, 1999; Malmberg and Maskell, 2006). The analysis of cross-citations of patent data and publications as well as the geographic concentration of knowledge-intensive activities indicate that knowledge does not move freely across space (Anselin et al., 1997; Audretsch and Feldman, 1996; Jaffe et al., 1993). The contention is that the likelihood of knowledge transfer increases with geographical proximity. This relates to the probability to identify or find relevant firm-external knowledge, which increases with geographic proximity (Storper and Venables, 2004). It also relates to the relative ease of transferring firm-external knowledge between collocated actors. This has been referred to as the 'sticky' nature of knowledge (Asheim and Isaksen, 2002; Nonaka and Takeuchi, 1995; Von Hippel, 1994).

Knowledge transfer is facilitated by geographic proximity for several reasons. Firstly, the partly tacit nature of knowledge makes transfer between distant partners difficult. Knowledge with a high tacit dimension is essentially impossible to codify and can therefore only be transferred directly from person-to-person, often in an interactive learning process (Lam, 2000; Malmberg and Maskell, 2006; Nonaka and Takeuchi, 1995; Polanyi, 1958). While knowledge with a high tacit component can be transferred over long-distance ties (Amin and Cohendet, 2005), such ties (e.g. within strategic alliances or joint ventures) are costly and time consuming to establish and maintain (Bathelt et al., 2004; Storper and Venables, 2004). Furthermore, knowledge exchange, and thus access to firm-external TC, is also supported by a shared institutional or social context, which often coincides with and is facilitated by geographic proximity (Boschma, 2005).

Even when it comes to non-sticky knowledge, such as codifiable information, geography is not unimportant. This is largely due to the fact that collocation tends to facilitate the search process (Gertler, 2003; Maskell, 2001; Nilsson, 2008). As the ability of firms to identify and evaluate knowledge (their absorptive capacity) is limited, having proximate access to actors with similar competencies is beneficial for the absorption of external TC. Firms tend to trust, and thus rely on, actors with whom they have frequent exchange, which is more likely when actors are collocated (Nilsson and Mattes, 2013).

In accordance with this reasoning, Cantwell and Piscitello (2002) argue that firms follow a path of technological accumulation that has unique characteristics based on the country or even region in which they are located (cf. Patel and Pavitt, 1991). Therefore the regionally available TC plays an important role for foreign firms' decisions of where to locate their technological activities (Cantwell and Piscitello, 2002). While traditional space-related transactions costs (e.g. costs associated with transportation and communication), discussed already by Coase (1937) and associated with static agglomeration economies (Malmberg et al., 1996), are becoming less important as a result of modern transport, information and communication technologies, spatially-bound skills and knowledge have increased in importance for firm-location (Malmberg and Maskell, 1999).

In other words, the probability that a firm accesses firm-external TC depends to a large extent on a spatial dimension. One way of capturing this is through the concept of *accessibility*, which has been used extensively in the fields of regional science and transport economies. Hansen (1959 p.73), one of this concept's pioneers, defines accessibility as 'the *potential* of opportunities for interaction'. This definition emphasizes the *level of the possibility of interaction* rather than just the ease of interaction. Weibull (1980) identified the most common interpretations of accessibility as: i) nearness, ii) proximity, iii) ease of spatial interaction, iv) potential of opportunities for interaction, v) potential of contacts with activities and suppliers. In this paper, accessibility is understood as the potential of opportunities for and ease of interaction with sources of firm-external TC. This does of course not imply that all firms have the same access to TC in close proximity, but rather that, all things being equal, the likelihood of accessing firm-external TC increases with geographical proximity.

Recently, the concept of accessibility has been used in several papers to measure the potential for and ease of knowledge interactions (Andersson and Ejermo, 2005; Andersson and Gråsjö, 2009; Andersson and Karlsson, 2007; Massard and Mehier, 2009). The disadvantage of this measure is that it does not allow distinguishing between the mechanisms through which firm-external TC are acquired. Evidence suggests that mechanisms such as labor mobility, collaboration, observation, social networks, etc. play an important role in sourcing firm-external TC (Breschi and Lissoni, 2001; Gulati, 1998; Tödtling et al., 2012; Tödtling et al., 2006; Zahra and George, 2002). The advantage of this measure is, however, that it can be applied for large datasets, such as all registered firms in a country. It allows to generate statistically generalizable results (Griliches, 1979).

Typically accessibility is modeled by an exponential distance-decay function, which goes back to Hansen (1959). Also, recent studies of knowledge accessibility have applied a similar function (Andersson and Ejermo, 2005; Andersson and Karlsson, 2007; Massard and Mehier, 2009). Accordingly, the accessibility of a firm located in region *r* to TC in other regions *s* is modeled as follows:

$$ACC_r = \sum_{s=1}^{n} TC_s e^{-\lambda t_{rs}}$$

ACC_r denotes the accessibility for a firm located in region *r* to TC available in other regions *s* = 1,...,n discounted by $e^{-\lambda t_{rs}}$. λ represents a sensitivity parameter with respect to the time-distance between two regions *r* and *s* denoted by t_{rs}. Time-distance measures the time required to travel to the desired resource. Time-distance is preferable to geographic distance or other neighborhood measurements (i.e. the location of the desired resource in neighboring regions) because it relates more closely to the actual spatial constraint for the probability and ease of knowledge interactions as experienced by firms. For instance, it has been shown that time-distance has a significant impact on the frequency of business meetings (Hugosson, 2001).

Finally, the total accessibility of each firm to firm-external TC comprises the above defined accessibility to TC in other regions ACC_r plus the firm-external TC available in the region where the firm is located as defined below:

$$ACC_i = ACC_r + (TC_r - TC_{ir})e^{-\lambda t_{rr}}$$

The accessibility ACC_i for firm *i* in region *r* equals to ACC_r plus the firm's accessibility to TC in the region r where it is located. Hence, the TC of firm *i* in region r (TC_{ir}) is subtracted from the total TC in this region (TC_r). Also, the distance decay function $e^{-\lambda t_{rr}}$ modeling the access to TC within region *r* is applied.

3 Description of the data and the model

3.1 Firm growth (dependent variable)

We measure firm growth (G) alternatively using turnover growth and employee growth. In both cases, we measure the yearly growth rate of Swedish firms between 2005 and 2007 in percent. We use the time period between 2005 and 2007 in order to avoid irregularities in growth patterns originating from the financial and economic crises starting in 2008. The data is taken from Statistic Sweden's database for Structural Business Statistics. We include all

Swedish firms with a minimum of 10 employees and 15 million SEK yearly turnover in any of the three years[1]. The total sample contains 15,682 firms.

3.2 Technological competencies

TC is measured using occupational and educational characteristics of employees in Sweden using Statistic Sweden's micro data. The Swedish Standard Classification of Occupations (SSYK) provides the basis for occupational characteristics. The Swedish Register of Education (SUN) is used for the field and level of education. We define individuals with high TC as follows:

- All employees registered as physical, mathematical and engineering science professionals. Individuals in this category have a skill level equivalent to at least three to four years of higher education and an academic degree.
- Employees registered as research and development managers.
- Employees registered as corporate managers that also have more than 2 years of university training or PhD education in a technological field including science, mathematics and computing as well as engineering, manufacturing and construction.
- Employees registered as managers of small enterprises that also have more than 2 years of university training or PhD education in a technological field including science, mathematics and computing as well as engineering, manufacturing and construction.

It is assumed that there is a time-lag between the availability or use of TC and when this materializes in firm growth. Therefore, all the TC variables are measured with a time-lag of one year as compared to the measurement of firm growth. Hence, TC was measured for the

[1] We excluded micro firms following approximately the OECD and EU definition for such firms.

period from 2004 to 2006. Since firm-level TC has been shown to be highly stable over time (Cantwell and Fai, 1999; Dierickx and Cool, 1989; Patel and Pavitt, 1990), it is valid to assume that the level of TC in firms and localities has also been similar in preceding years.

3.3 Level of firm-internal technological competencies

The level of firm-internal TC, for which the term technological intensity (TI) will be used interchangeably, is measured on the firm level as the average share of employees in percent with high TC from 2004 to 2006.

3.4 Accessibility to firm-external technological competencies

Firm-external TC is measured as the total number of individuals with high TC employed outside the firm. In order to construct the accessibility measure (ACC), the average number of firm-external TC in the period from 2004 to 2006 was calculated for each Swedish municipality. The Swedish municipalities represent the regional units. The time-distance between Swedish municipalities is measured as driving time in minutes by car using the most efficient route in 2004. The time-distance values were provided by the Swedish Transport Administration. For the sensitivity parameter, we used a value of 0.017, which is based on the empirically derived distance sensitivity of Swedish interregional business trips (Hugosson, 2001; Andersson and Ejermo, 2005). In some studies, different time-sensitivity parameters have been used for inter- and for intra-municipal accessibility (Andersson and Ejermo, 2005). However, as our results were not sensitive to such differences, we set λ for both inter- and intra-municipal accessibility to 0.017[2].

In accessibility studies, the ability to locate a firm geographically is of crucial importance. For firms with only one establishment this is unproblematic. For multi-establishment firms,

[2] We tested models with different values for λ and the results were only affected marginally.

however, this is potentially more problematic. In this study, we locate multi-establishment firms in the municipality where their headquarters are situated. This means that we underestimate the accessibility to firm-external TC of firms with more than one place of work. In particular, this is potentially problematic for large firms. In order to assess the implications of this decision, we calculated our model with a subgroup of firms that have only one establishment. As the results only changed marginally, we consider that our approach is valid.

3.5 Models

The basic model is as follows:

$$G_i = \alpha + \beta_1 TI_i + \beta_2 ACC_i + \beta_3 lnS_i + \beta_4 lnS2_i + \beta_5 I_{1i} + \cdots + \beta_{85} I_{81i} + \varepsilon_i$$

Where firm growth G of firm i is explained by its technological intensity TI_i and its accessibility to firm-external technological competencies ACC_i. We control for firm size and industry. The indicator for firm size lnS_i is the natural logarithm of the average total employment of firms between 2004 and 2006 and, in order to control for non-linear effects, its square $lnS2_i$. Further, we included industry dummies $I_{1i,\dots,81i}$ following the 2-digit Swedish National Industry classification. The basic model allows testing hypotheses 1 and 2.

As discussed in the conceptual section, there are reasons to assume that the relationships between the level of firm-internal TC and firm growth as well as between accessibility to firm-external TC and firm growth are conditional to firm size, which led to the formulation of hypotheses 3a and 3b. These relationships are modeled by introducing the interaction variables $TI_i * lnS_i$ and $ACC_i * lnS_i$ into the basic model:

$$G_i = \alpha + \beta_1 TI_i + \beta_2 TI_i * lnS_i + \beta_3 ACC_i + \beta_4 ACC_i * lnS_i + \beta_5 lnS_i + \beta_6 lnS2_i +$$

$$\beta_7 I_{1i} + \cdots + \beta_{87} I_{81i} + \varepsilon_i$$

Finally, hypothesis 4a stipulates a positive relationship between firm performance and the combination of the level of firm-internal TC and access to firm-external TC. Hypothesis 4b stipulates that this relationship is mediated by firm size. These hypotheses will be tested by including the interaction variables $TI_i * ACC_i$ as well as $TI_i * ACC_i * lnS_i$. We exclude, however the individual effects of TI and accessibility to firm-external TC because they correlate highly with the interaction variables and thus reduces the significance for each of these variables. Also, we aim at testing specifically the relationship between the combination of TI and accessibility to firm-external TC on firm growth. Hence, the model is as follows:

$$G_i = \alpha + \beta_1 TI_i * ACC_i + \beta_2 TI_i * ACC_i * lnS_i + \beta_3 lnS_i + \beta_4 lnS2_i +$$

$$\beta_5 I_{1i} + \cdots + \beta_{85} I_{81i} + \varepsilon_i$$

We have tested the models for multicollinearity, non-linearity of the explanatory variables and significant outliers and could not detect significant violation of the assumptions. As corrective action against heteroskedasticity, we estimated the models using the method of robust standard errors. In Annex 1 we present descriptive statistics for each variable as well as the correlations between them.

3.6 Results

All three models are calculated using alternatively turnover growth and employee growth as dependent variable. In general, table 1 shows that the results are very similar regardless which dependent variable is used to measure firm growth.

[INSERT TABLE 1 ABOUT HERE]

Model 1 allows testing for hypotheses 1 and 2, which stipulate that TI and accessibility to firm-external TC should be positively related to firm growth. Both hypotheses are supported by our results.

Model 2 is designed to test hypotheses 3a and 3b, which say that the relationship between TI and firm growth as well as accessibility and firm growth are mediated by the size of firms. Based on our results, hypothesis 3a is rejected. This means that TI appears to matter for firm growth regardless the size of the firm. In contrast, there is some support for hypothesis 3b that accessibility is of lower importance for bigger firms. The relevant coefficient is negative and significant at the 10% significance level.

In Model 3 we test whether the combination of a high level of firm-internal TC with a high access to firm-external TC is positively related to firm performance (hypothesis 4a). Also, we use this model to test that this relationship is mediated by firm size (hypothesis 4b). Both hypotheses are strongly supported by our results, hypothesis 4a at 1% significance level and hypothesis 4b at 5% significant level.

4 Conclusions

In this paper we have analyzed the relationship between technological competencies and firm performance accounting for both firm-internal TC and potential access to firm-external TC. We discuss conceptually the interplay between internal and external competencies and identify firm size as an important mediating factor. We argue that existing studies are often biased towards large firms because of the availability and choice of indicators. Also, we elaborate on the interdependencies between internal and external competencies and thus motivate empirical work considering both. In contrast to existing research, for example using case studies to analyze complementarities between internal and external competencies in relation to strategic alliances and mergers & acquisitions, we analyze these relationships with a large dataset comprising 15,682 firms in 290 Swedish municipalities. In order to do so, we combine novel indicators, based on occupational statistics, with measures of time-distance accessibility to external TC.

Overall, our results support the basic argument that TC matters for firm performance (e.g. De Carolis, 2003; Franko, 1989; Lee, 2010). TC, in our study, is represented by individuals who are registered in occupations that imply a high level of TC (for example science professionals, R&D managers, and corporate managers with scientific training). As regards firm-internal TC, our results show a positive relationship between firm growth and technological intensity (i.e. the share of TC in the workforce of the firm). As regards firm-external TC, we introduce the concept of accessibility. This concept captures the potential of opportunities for and the ease of interaction with firm-external TC. We argue that, all other things equal, the potential access to firm-external TC increases with geographic proximity to such sources, i.e. if individuals with a high level of TC are located close by. This builds on arguments advanced in the literature on economic geography, that knowledge does not move freely across space (e.g. Gertler, 2003). The importance of geography relates to the spatially bounded nature of, particularly tacit, knowledge; the ability to identify relevant knowledge; and the relative ease of interactive learning associated with collocation (Lam, 2000; Malmberg and Maskell, 2006; Von Hippel, 1994). We find that accessibility to firm-external TC is positively related to firm growth.

In this paper, we argue that particularly the combination of a high level of firm-internal TC with a high access to firm-external TC should be conducive for firm growth. This can be explained through the argument of absorptive capacity (Cohen and Levinthal, 1990), where firm-internal characteristics influence the firm's ability to identify and appropriate firm external knowledge. The internal competencies and skills of a firm greatly influence its choice of collaboration partners (cf. Neffke and Henning, 2013) and its attractiveness as a collaboration partner for other firms (Ter Wal and Boschma, 2011). However, firms may partly substitute firm-internal TC with firm-external TC. This substitution is expected to be easier in regions with high accessibility to firm-external TC, i.e. for firms that find such resources in close geographic proximity. Hence, the relationship between firm performance and the combination of internal and external TC is not necessarily positive, especially if the substitution effect prevails. Interestingly, we find strong support that a high level of firm-internal TC combined with a high access to firm-external TC is positively related to firm growth. This indicates that the capacity of firms to benefit from external knowledge is indeed contingent on the level of similar internal knowledge. Also, it shows that internal and external TC rather complement than substitute each other. We also find that this relationship is more pronounced for small firms than for large firms. Hence, it appears that in particular small firms characterized by high technology intensity have an advantage of being located in a region with high firm-external TC.

Finally, our study reveals a number of interesting research questions that could not be answered in this paper and that require a more nuanced analysis of specific issues, including: How are firm-internal and firm-external TC integrated and combined? How important are diversity and relatedness as regards firm-internal and firm-external TC? To what extend is internal TC complemented or supplemented by external TC and how does this differ depending on the firm's access to TC in close proximity? Can international linkages complement a lack of access to TC locally? What is the role of TC for micro and small firms? How do micro and small firms source firm-external competencies, particularly in locations with low access to such? All these represent highly interesting avenues for future research.

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Table 1: Regression with robust standard errors

	Employment Growth			Turnover Growth		
	Model 1	Model 2	Model 3	Model 1	Model 2	Model 3
TI	0.0506**	0.124**		0.0815***	0.144**	
	(0.0199)	(0.0565)		(0.0262)	(0.0734)	
TI*lnS		-0.0194			-0.0167	
		(0.0148)			(0.0194)	
ACC	0.0312***	0.0836***		0.0263**	0.0897**	
	(0.00966)	(0.0304)		(0.0115)	(0.0358)	
ACC*lnS		-0.0146*			-0.0177*	
		(0.00813)			(0.00919)	
TI*ACC			0.00417***			0.00514***
			(0.00137)			(0.00170)
TI*ACC*lnS			-0.000741**			-0.000792**
			(0.000308)			(0.000381)
lnS	-1.414**	-1.379**	-1.561**	-0.760	-0.701	-0.897
	(0.643)	(0.643)	(0.646)	(0.782)	(0.773)	(0.781)
lnS2	0.0450	0.102	0.0855	0.00739	0.0704	0.0469
	(0.0717)	(0.0750)	(0.0719)	(0.0856)	(0.0886)	(0.0845)
Industry	controlled***	controlled***	controlled***	controlled***	controlled***	controlled***
Constant	8.158***	7.264***	8.939***	11.97***	10.91***	12.63***
	(1.362)	(1.404)	(1.355)	(1.684)	(1.712)	(1.672)
Observations	15.682	15.682	15.682	15.682	15.682	15.682
r2	0.0204	0.0208	0.0204	0.0363	0.0366	0.0367

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Annex 1: Descriptive statistics and correlations

Variable	Mean	Std.Dev.	Min	Max
TG	10.37	20.47	-84.64	467.88
EG	4.72	17.47	-77.60	722.14
TI	4.52	12.99	0.00	98.77
ACC	25.11	16.48	0.46	52.45
lnS	3.59	0.99	2.30	10.40
TI*lnS	17.43	51.84	0.00	648.35
ACC*lnS	91.47	70.70	1.21	541.56
TI*ACC	152.69	529.05	0.00	5134.94
TI*ACC*lnS	592.57	2150.52	0.00	33774.41
lnS2	13.84	8.77	5.30	108.06

	TG	EG	TI	ACC	lnS	TI* lnS	ACC* lnS	TI* ACC	TI* ACC* lnS	lnS2
TG	1.000									
EG	0.519	1.000								
TI	0.043	0.040	1.000							
ACC	0.011	0.037	0.183	1.000						
lnS	-0.026	-0.046	0.094	0.086	1.000					
TI*lnS	0.035	0.029	0.961	0.182	0.197	1.000				
ACC*lnS	-0.006	0.011	0.195	0.885	0.472	0.245	1.000			
TI*ACC	0.045	0.042	0.901	0.305	0.086	0.877	0.303	1.000		
TI*ACC*lnS	0.035	0.030	0.860	0.294	0.173	0.910	0.347	0.959	1.000	
lnS2	-0.026	-0.045	0.087	0.093	0.981	0.195	0.483	0.082	0.173	1.000

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