Frontiers of Entrepreneurship Research

Volume 30 | Issue 18
CHAPTER XVIII. PUBLIC POLICY, OTHER

Article 2

6-12-2010

WHAT TURNS KNOWLEDGE INTO INNOVATIVE PRODUCTS? THE ROLE OF ENTREPRENEURSHIP AND KNOWLEGE SPILLOVERS

Joern H. Block
Erasmus University Rotterdam, block@ese.eur.nl

Roy Thurik
Erasmus University Rotterdam

Haibo Zhou
Erasmus University Rotterdam

WHAT TURNS KNOWLEDGE INTO INNOVATIVE PRODUCTS? THE ROLE OF ENTREPRENEURSHIP AND KNOWLEGE SPILLOVERS

Joern H. Block, Erasmus University Rotterdam, The Netherlands
Roy Thurik, Erasmus University Rotterdam, The Netherlands
Haibo Zhou, Erasmus University Rotterdam, The Netherlands

ABSTRACT

The knowledge spillover theory of entrepreneurship seeks to explain the sources of entrepreneurship and its consequences with regard to economic performance. This paper extends the theory and links it to innovation performance. We propose that a high rate of entrepreneurship facilitates the process of turning knowledge into innovative products, while it has no effect on the relationship between knowledge and imitative products. We use European country-level data to test our propositions. Our results show that a high rate of entrepreneurship increases the chances that knowledge will turn into innovative products. The findings highlight the importance of entrepreneurs in the process of the commercialization of knowledge. Implications for innovation policy are discussed.

INTRODUCTION

Endogenous growth theory assumes that an economy automatically benefits from its investments in new knowledge (Lucas, 1988; Romer, 1990). The idea is that knowledge behaves like a public good that an entire economy can use. This use leads to economic growth. Also, in the empirical world of the R&D capital approach (Mansfield, 1965; Griliches, 1998, 2000), the development of total factor productivity (TFP) is simply explained using an R&D stock variable.[1] Although there is, of course, a great deal of evidence that knowledge (R&D stock) leads to growth (TFP growth), some countries seem to benefit more from investments in new knowledge than others do. The US, for example, is considered to be much stronger than Europe in the commercialization of new knowledge. This effect is sometimes referred to as the Swedish paradox (Ejermo and Kander, 2006) or the European paradox (Audretsch, 2007a). Investments in new knowledge are only a necessary condition; new knowledge still needs to be exploited and put to commercial use so that it can translate into a higher level of competitiveness and subsequent economic growth. The barrier between knowledge and its commercialization is termed the knowledge filter (Acs et al., 2005; Mueller, 2006; Audretsch, 2007a).

This paper analyzes the relationship between new knowledge and innovation performance and, in particular, the role of entrepreneurship with regard to the mechanism that translates knowledge into innovative products. We use and extend the knowledge spillover theory of entrepreneurship (Audretsch and Lehmann, 2005; Audretsch and Keilbach, 2007, 2008; Acs et al., 2009) and link it to the field of innovation. So far, the theory has largely not addressed questions of innovation and innovation performance. Its main concern has been the role of entrepreneurship in turning knowledge into economic growth. The question of *how* exactly entrepreneurship turns knowledge into economic growth is left unanswered. This is unsatisfactory because to design an effective growth policy, policymakers need to understand the exact mechanisms through which entrepreneurship leads to economic growth. Our extension of the knowledge spillover theory to the field of innovation is a first step in this direction.

Prior research presents entrepreneurship as an additional production factor termed entrepreneurship capital (Audretsch, 2007a). However, in this sense, it does not contribute to our understanding of how the transformation of knowledge into economic growth works. The main question is *why* entrepreneurship leads to growth. Also, literature surveys of the influence of entrepreneurship on economic growth (Carree and Thurik, 2003; Van Praag and Versloot, 2007; Braunerhjelm, 2008) are relatively vague about this: entrepreneurship is expected to lead to diversity, innovation, competition, employment, learning, etc., at which point growth occurs[2]. In the present paper, we address this question by focusing on innovation and innovation performance as outcome variables (not economic growth). Hence, we make a first attempt to integrate the knowledge spillover theory into the innovation literature.

Our focus, and hence our unit of observation, is at the country level and not that of the individual firm. We test our proposed extensions of the knowledge spillover theory of entrepreneurship using a panel dataset that covers the innovation activity of 21 European countries in four waves corresponding to the period from 1996 to 2006. The results are clear: entrepreneurship is found to be an important driver that turns knowledge into innovative products, while it has no impact on imitative products. This is precisely what our extension of the knowledge spillover theory of entrepreneurship predicts. Entrepreneurs as individuals are risk-takers; they play an important role when risk is involved. This is the case with innovative products but less so with imitative products. With this result, the paper contributes to our understanding of why and under which conditions entrepreneurship leads to economic growth.

The remainder of this paper is organized as follows. Section 2 introduces the knowledge spillover theory of entrepreneurship. Section 3 extends the knowledge spillover theory of entrepreneurship, linking it to innovation performance. Section 4 describes our data and the empirical model. Section 5 reports our regression results, which are then discussed in Section 6.

RELATED LITERATURE

Knowledge Spillovers and Geographical Boundaries

The production of knowledge can lead to spillovers: individuals or organizations other than the creators of knowledge may benefit from the knowledge that the creator has produced. Thus, by investing in knowledge, a firm not only increases its own level of knowledge but also makes a contribution to the aggregate stock of knowledge (Romer, 1986; Lucas, 1993; Griliches, 1998). For example, if a firm produces new knowledge and is granted a patent, the information included in the patent becomes accessible to the general public and to competitors. A competitor may use the information from the patent for its own research and invest in related knowledge, which might then lead to new patents or innovative products: knowledge may spill over from one firm to another. There exists extensive research on knowledge spillovers in multiple contexts, such as technology transfer (e.g., Mueller, 2006), innovation networks (e.g., Breschi and Lissoni, 2001), technology clusters (e.g., Link and Scott, 2005), and the evolution of industries (e.g., Iammarino and McCann, 2006). One of the recurring findings is that geographical proximity matters if knowledge spillovers are to occur. Although it is possible that knowledge spills over to firms or individuals far away from the creator of knowledge, it has been shown that these spillovers are more likely to occur on a local level (Jaffe et al., 1993; Bottazzi and Peri, 2003).

The Knowledge Spillover Theory of Entrepreneurship

Entrepreneurship is identified by its role in opportunity recognition, discovery, and creation (Shane and Venkataraman, 2000). Little is known, however, about the source of opportunities. The knowledge spillover theory of entrepreneurship (Audretsch and Lehmann, 2005; Audretsch and Keilbach, 2007, 2008; Acs et al., 2009) helps to close this gap. Knowledge spillovers are suggested as a possible source of entrepreneurial opportunities. This has also been termed endogenous entrepreneurship[3]. Due to the non-rival nature of knowledge as an asset, it may spill over such that the producers of knowledge are not able to appropriate the entire value of their knowledge for themselves. These spillovers serve as a source of opportunities for other firms and for individuals who want to start their own business. The knowledge spillover theory of entrepreneurship states that entrepreneurial activity is greater in the presence of higher investments in knowledge. This argument is supported by Audretsch and Lehmann (2005), among others, who show that regions with greater investments in new knowledge also have higher start-up rates. Another facet of the theory refers to entrepreneurial performance. Based on the assumption that knowledge spillovers increase economic performance (Lucas, 1988; Romer, 1990; Glaeser et al., 1992) and that this relationship is moderated by geographical proximity (Jaffe et al., 1993; Bottazzi and Peri, 2003), it is suggested that opportunities for entrepreneurship are superior when the ability to access knowledge spillovers from geographically proximate sources is greater. This can be the case if the entrepreneur is located in close proximity to universities, large high-tech firms or other research-intensive institutions that produce knowledge (Audretsch et al., 2005; Mueller, 2006).

ENTREPRENEURSHIP AND ITS RELATION TO INNOVATION

The purpose of this paper is to extend the knowledge spillover theory of entrepreneurship and link it to innovation and innovation performance. As summarized in the preceding section, most existing work about the knowledge spillover theory of entrepreneurship is about the sources of entrepreneurship and its consequences with regard to economic performance. The link between entrepreneurship and innovation is made only indirectly; for example, it is suggested that entrepreneurship increases the level of economic output by serving as a mechanism that facilitates the commercialization of knowledge. No explicit link has been made between entrepreneurship and innovation. The purpose of this paper is to close this gap. In the following, we argue that entrepreneurship is more likely to influence the process that leads knowledge to be converted into innovative products as opposed to imitative products.

Innovation relates to two interrelated processes: the production of knowledge[4] and the exploitation of knowledge. We focus on the exploitation phase and particularly on the mechanism that turns knowledge into innovative products. The commercialization of knowledge, in particular new knowledge, includes efforts such as financing product development or market research. The outcome of this process is often highly uncertain and requires a risk-taking attitude from those actors who manage the process. Having an entrepreneurial attitude comes into play at this stage. Entrepreneurs are considered different from other individuals; for example, they are considered to have an above-average level of willingness to take risks (Kihlstrom and Laffont, 1979; Brockhaus, 1980), a tolerance for ambiguity (Timmons, 1976; Schere, 1982), a great need for achievement (McClelland, 1961), and a preference for autonomy (Benz and Frey, 2008). In particular, being a risk-taker and having a tolerance for ambiguity are crucial in managing the process of commercializing new knowledge. A high rate of entrepreneurship and exposure to an entrepreneurial climate facilitate the process of turning knowledge into innovative products. This leads us to propose the following hypothesis:

Entrepreneurship moderates the relationship between knowledge and innovation performance.

Innovation performance may relate to the number of new products introduced to the market or the amount of sales generated with innovative products.

DATA AND EMPIRICAL MODEL

Data Sources

Our study combines data from the Community Innovation Survey (CIS)[5], the COMPENDIA database[6], and the OECD Economic Outlook Database[7].

The CIS is commissioned by the European Commission and records the innovation activity of firms in the EU member states, in EU candidate countries, and in Iceland and Norway. The first CIS took place in 1993, using a pilot version (CIS1). Since then, four additional surveys have been carried out: CIS2 (years 1996-1998), CIS3 (years 1998-2000), CIS4 (years 2002-2004), and CIS2006 (years 2004-2006). The survey unit of the CIS is the enterprise, and the target population is the total population of enterprises in the particular country. Because sampling rates may differ across countries, the CIS uses a stratified sampling procedure and weighting procedures to ensure that the samples are representative of the total population of enterprises in each country. The results of the firm-level CIS are aggregated and transmitted to Eurostat on a compulsory basis. CIS data are accepted in the research community and have been widely used in innovation research (Arundel, 2001; Mairesse and Mohen, 2002, 2004; Hoelzl, 2009).

COMPENDIA (COMParative ENtrepreneurship Data for International Analysis) is developed and maintained by EIM Business and Policy Research (a Panteia company) in the Netherlands. The database summarizes and harmonizes information about the number of business owners and the size of the labor force from the following resources: the OECD databases, the ILO Yearbook of Labour Statistics and the European Observatory for SMEs. The quotient of these two variables is called the business ownership rate (Van Stel, 2005). Business ownership includes all unincorporated self-employed persons and owner-managers of incorporated businesses (OMIBs) (Van Stel, 2005). Although it has been argued that business ownership is not synonymous with entrepreneurship, Carree et al. (2002) acknowledge that business ownership level is a fair reflection of the level of entrepreneurship in a particular country. The main advantage of this harmonized dataset is that it makes entrepreneurship activity comparable across countries and over time. The latest version of the COMPENDIA consists of 23 OECD countries over the period of 1972-2007.

The OECD Economic Outlook Database indicates historical trends and future projections for a wide range of macro indicators that illustrate the demographic, social, economic and environmental developments of a country. These include gross domestic product, rate of unemployment or deflators and prices. The dataset encompasses longitudinal information on macro indicators from the 30 OECD member countries and 6 selected non-OECD countries. We rely on this database to build our country-specific control variables.

Our final assembled dataset covers aggregated information on innovation activity from manufacturing firms (NACE 15-37)[8], business ownership rates, and macro indicators of 21 European countries[9] in four waves corresponding to the period from 1996 to 2006. We restrict our sample to the manufacturing sector to ensure that our results are not driven by differences in

industry structure between countries. Because not all countries are included in each wave, our final dataset takes the form of an unbalanced panel dataset.

Dependent Variable

Innovation performance: the measurement of innovation and innovation performance embraces various dimensions and varies according to firms and their life-cycle phases. Innovation and its performance can be measured in many ways, such as with the turnover of new products, increases in productivity or decreases in production cost as a result of introducing new processes, and customer satisfaction with new products or services (for an overview, see Hauser and Zettelmayer, 1997). The CIS measures new product performance in two ways: (1) with shares of turnover attributable to new or significantly improved products that are *new to the firm* (we have termed this imitation performance) and (2) with shares of turnover attributable to new or significantly improved products that are *new to the market* (we have termed this innovation performance). We argue that entrepreneurship and an entrepreneurial attitude matter particularly with regard to innovation performance, and less so with imitation performance.

Independent Variables

Rate of knowledge-intensive firms: As discussed above, the production of new knowledge is a crucial factor leading to innovation. We measure a country's level of knowledge as the share of firms that have applied for at least one patent in the survey year. We consider this measure a good proxy for knowledge in the context of this study: patents are property rights granted by a patent authority such as the European Patent Office (EPO). For a patent to be granted, the invention must be non-trivial and of potential commercial value. Patents have been used in a number of studies as a proxy for knowledge and knowledge spillover (Jaffe et al., 1993, 2000; Acs et al. 2002, Furman et al., 2002). The data were obtained from the CIS.

Entrepreneurship rate: Due to the heterogeneous context of entrepreneurship, no unique variable exists that measures entrepreneurship or entrepreneurial climate. Commonly used measures are self-employment rates, business ownership rates, and numbers of new firm start-ups (Parker 2004, pp. 5-8). We use the business ownership rate to measure entrepreneurship. Our results, however, also hold when we use the rate of self-employment as a proxy for entrepreneurship. The business ownership rate is calculated as the share of business owners in the total labor force. Business owners are defined as individuals whose main occupation is self-employment. This also includes owner-managers of incorporated businesses. The data were obtained from COMPENDIA.

Control variables: To control for macro-economic influences, two macro-economic variables are included in the regression models: *GDP* and *GDP per capita*. The variables are taken from the OECD Economic Outlook Database. To achieve comparability over time, the values of *GDP* and *GDP per capita* were adjusted to prices from 1995. Both variables are represented as logged values and refer to the country's size or level of wealth.

Empirical Model

The following two pooled OLS equations are used for the empirical analysis:

$$I_{i,t} = \alpha + \beta_1(K_{i,t}) + \beta_2(E_{i,t}) + \beta_3(K_{it}E_{it}) + \beta_4(Controls_{i,t}) + \beta_5(Years_t) + \varepsilon_{i,t},$$

where *I* is either *Innovperf* (innovation performance measured according to the share of turnover attributable to new or significantly improved products that are *new to the market*;) or *Imitaperf* (imitation performance measured according to the share of turnover attributable to new or significantly improved products that are *new to the firm*); *K* denotes the rate of knowledge-intensive firms measured by the share of firms that applied for at least one patent in the last three years; *E* denotes the business ownership rate as a proxy for the entrepreneurship rate; *Controls* denotes the control variables, which are the natural logarithm of *GDP* and the natural logarithm of *GDP per capita*; *Years* corresponds to year dummies for the years 1998, 2000, 2004, and 2006 and *i* and *t* are country and year indices, respectively. Table 1 describes the construction of the variables in more detail. To conduct a robustness check, we also estimate random-effects and fixed-effects regressions (Wooldridge, 2002) using the same variables.

RESULTS

Descriptive Statistics

Some descriptive statistics for the variables are presented in Table 2. The mean percentage of turnover with innovative products is 8% (with variation from 1% to 24%). The mean percentage of turnover with imitative products is 13% (with variation from 4% to 41%). The mean rate of entrepreneurship is 11% (with variation from 5% to 21%), and the mean proportion of firms that applied for a patent is 10% (ranging from 2% to 27%). Table 3 shows a correlation table. Innovation and imitation performance are not correlated ($r=0.05$, $p>0.1$), which indicates that they relate to different characteristics of new products (and countries). Except for the correlation between *knowledge* and the natural logarithm of *GDP per capita*, all correlations are below 0.5. With innovation and imitation performance as the dependent variables, the variance inflation factors (VIFs) do not exceed 3. In conclusion, multicollinearity is unlikely to be an issue. Still, we use step-wise regressions to learn about the interrelationships among the independent variables.

Pooled OLS Regressions of Innovation Performance

Table 4 shows the results of pooled OLS regressions regarding innovation performance (standard errors are clustered). The empirical analysis is conducted in four steps. Model I is a baseline model in which we only include the macro-economic control variables and the year dummies. The baseline model already explains 13% of the variation in *innovation performance* (our dependent variable). In Model II, we add the knowledge variable to the baseline model and test for the effect of *knowledge* on *innovation performance*. As expected, a positive relationship is found in that a higher share of knowledge-intensive firms leads to higher innovation performance ($\beta=0.27$, $p<0.1$). The explanatory power of the model increases by 9%. The result confirms that the stock of knowledge is an important determinant of innovation performance. In Model III, we include the entrepreneurship variable in the model. The rate of entrepreneurship itself seems not to have an impact on innovation performance ($\beta=0.09$, $p=0.67$). The effect of the knowledge variable hardly increases from $\beta=0.27$ ($p<0.10$) in Model II to $\beta=0.31$ ($p<0.05$) in Model III. In Model IV, we test for the moderation effect of entrepreneurship: the interaction term shows a positive effect ($\beta=0.07$, $p<0.05$). Explanatory power increases by 7% points: from $R^2=22\%$ in Model III to $R^2=29\%$ in Model IV. A higher rate of entrepreneurship seems to increase the rate by which knowledge leads to innovative products. This result indicates that a higher rate of entrepreneurship facilitates the process of the commercialization of knowledge. Entrepreneurship is found to moderate the relationship between knowledge and innovation performance. To determine whether the OLS model produces consistent results, we performed a Breusch-Pagan test for random effects (Breusch and Pagan, 1980). The test shows significant results for Models I-II and insignificant

results for Models III-IV. Thus, we can conclude that OLS coefficients are consistent in Models III-IV and inconsistent in Models I-II.

Pooled OLS Regressions of Imitation Performance

As a further test of the role of entrepreneurship, we investigate whether entrepreneurship in fact does *not* moderate the relationship between knowledge and imitative products. Table 5 shows the results of the regressions regarding imitation performance. Knowledge clearly leads to more imitative products. A higher rate of knowledge-intensive firms increases turnover with imitative products (β=0.51, p<0.05, Model II). Table 5, however, also shows that entrepreneurship does not have an effect with regard to imitation performance. Neither the entrepreneurship variable included directly (β=-0.29, p=0.13, Model III) nor the interaction term (β=-0.02, p=0.65, Model IV) show significant results. Hence, a higher rate of entrepreneurship does not lead to more imitative products. This result re-confirms our proposition that entrepreneurship moderates the relationship between knowledge and innovation performance but does not have an impact on the relationship between knowledge and imitation performance. The results should be interpreted with caution because the Breusch-Pagan test for random effects (Breusch and Pagan, 1980) yields significant results. OLS coefficients may be inconsistent, which is why we also estimate random- and fixed effects regressions (see robustness checks below).

Further Results from the Regressions

Our analysis yields several other interesting findings. First, there seems to be a positive time trend with regard to innovation performance (ß=1.18, p<0.01, Table 4, Model III) and a negative time trend with regard to imitation performance (ß=-3.57, p<0.01, Table 5, Model III). The ratio of innovative versus imitative products has increased over time in the 21 European countries. This phenomenon is one of the many indicators of the switch from the 'managed' to the 'entrepreneurial' economy (Audretsch and Thurik, 2001). Second, the regressions for imitation performance have higher R^2 values than the regressions for innovation performance (R^2=61% vs. 29% in Model IV). This substantial difference is due to the effect of the year dummies: inclusion of year dummies alone already explains 42% of the variation in imitation performance, while it only explains 5% of the variation in innovation performance. The autonomous decline in imitative performance seems to override the autonomous increase in innovative importance. This phenomenon is one of the many indicators of the decline in competitiveness of European countries. Finally, the finding that knowledge plays a role with both innovation (ß=0.27, p<0.1, Table 4, Model II) and imitation performance (ß=0.51, p<0.05, Table 5, Model II) is in line with what we expected. Investments in knowledge increase a country's level of absorptive capacity (Cohen and Levinthal, 1989, 1990), which has an effect on both imitation and innovation performance.

Robustness Checks

To check the robustness of our results, we estimate random- and fixed-effects models (see Tables 6 and 7). Both models confirm our main finding that entrepreneurship moderates the relationship between knowledge and innovation performance (Table 6: Model II: β=0.07, p=0.03; Model IV: β=0.12, p=0.01) but also indicate that it does *not* have an impact on the relationship between knowledge and imitation performance (Table 7: Model II: β=-0.04, p=0.46). A Hausman specification test is used to compare the coefficients of the random-and fixed-effects regressions (Hausman, 1978). In all estimations, the test shows an insignificant result (p>0.10); the random-effects coefficients can be used because they do not differ in a systematic way from the fixed-

effects coefficients. The fact that our results also hold for a fixed effects specification is reconfirming. We can conclude that our main findings hold irrespective of country-specific variables such as openness to trade or geographic location.

As further robustness checks, we estimate seemingly unrelated regression models (SUR) and two-stage simultaneous equation models in which the entrepreneurship variable is treated as endogenous. The moderation effect of entrepreneurship on the relationship between knowledge and innovation performance is similar to the effects in the other models. The estimation results are available from the authors upon request.

DISCUSSION

Innovation in the Knowledge Spillover Theory of Entrepreneurship

Both the endogenous growth theory and the R&D capital approach point to knowledge as a major driver of economic growth. Less is known about *how* this source of economic growth has its effect on growth. This means that it is difficult for policymakers to identify policy instruments that promote growth. Glaeser et al. (1992) have established that knowledge and ideas do not spill over automatically: in the context of cities, it takes competition and diversity to generate growth (see also Audretsch, 1995; Audretsch and Feldman, 1996). The important finding that knowledge does not automatically spill over has given rise to the development of the concept of the knowledge filter, i.e., the impediments that keep knowledge from spilling over from where it is created to where it can be commercialized (Acs et al., 2005; Audretsch, 2007a). Independently of the investigation of the role of knowledge, a different strand of literature has developed that emphasizes the role of entrepreneurship in economic growth. See Audretsch and Thurik (2001) and surveys such as Carree and Thurik (2003) and Van Praag and Versloot (2007). This development has culminated in the view that the older 'managed' economy has been replaced by a newer 'entrepreneurial' economy (Audretsch and Thurik, 2001; Audretsch, 2007b). The view that entrepreneurship is an independent production factor like human, physical and knowledge capital has led to the introduction of entrepreneurship capital into the production function (Audretsch and Keilbach, 2004) and to various studies showing that entrepreneurship indeed influences economic growth (Erken et al., 2009). Although there are many indications in the knowledge literature that the (spatial) organization of business plays a role (Audretsch and Feldman, 1996) and in the entrepreneurship literature that knowledge and its diffusion play a role (Audretsch and Thurik, 2001), it took the knowledge spillover theory of entrepreneurship to bring this all together (Audretsch and Lehmann, 2005; Audretsch and Keilbach, 2007, 2008; Acs et al., 2009). This theory is sometimes presented as the missing link (Acs et al., 2005). However, within this missing link, there is another missing link: the role of innovation. Knowledge and entrepreneurial activity may ultimately lead to economic growth, but not without first producing innovative products. The latter missing link is addressed in the present paper using a panel dataset for the aggregate innovation activity of 21 European countries collected in four time waves. Our results clearly show that entrepreneurship moderates the relationship between knowledge and innovation but has no impact on the relationship between knowledge and imitation. In other words, our results show that countries with a high rate of entrepreneurship perform better in terms of innovation performance.

Figure 1 illustrates our extension of the knowledge spillover theory to the area of innovation. The production of knowledge increases the aggregate stock of knowledge (arrow 1). Existing or new firms can draw from this aggregate stock and develop both imitative (arrow 2) and innovative products (arrow 3).[10] Entrepreneurship moderates the relationship between the aggregate stock of

knowledge and the number of innovative products (innovation performance) (arrow 4), but it has *no* impact on the relationship between the aggregate stock of knowledge and the number of imitative products (imitation performance).[11] Both imitative products and innovative products may lead to economic growth. The mechanisms involved, however, are different and may depend on the country's level of development (Vandenbussche, Aghion and Meghir, 2006). We will not go deeper into this discussion because it is beyond the scope of our paper.

Explanations for the Moderating Role of Entrepreneurship

Our findings regarding the role of entrepreneurship are clearly in line with a Schumpeterian view of entrepreneurship. In his early works, Schumpeter argued that entrepreneurs are not necessarily inventors or knowledge creators (Schumpeter, 1934). Rather, their role is to transform knowledge into products. Being innovators, they are responsible for the introduction of new products, the creation of new production methods, the opening of new markets, etc.. Schumpeter saw the entrepreneur as an agent who can cope with uncertainty, thereby inducing technological change and progress. Our findings regarding the role of entrepreneurship support this view: entrepreneurship moderates the relationship between knowledge and innovation performance but has no impact on the relationship between knowledge and imitation performance. The former relationship is characterized by a high degree of uncertainty, whereas the latter is not necessarily so.

Because entrepreneurship is often related to small firms, our findings are also in line with the view that small firms face relatively lower costs of experimentation than do large firms. The formers' potential losses from innovation are bounded at a low level (Jovanovic, 1982). In addition, small firms may have an advantage with regard to rewarding their employees for high-value innovation (Wiggins, 1995).

Implications for Innovation Policy

Our main finding that entrepreneurship moderates the relationship between knowledge and innovation performance has important policy implications. From an innovation policy perspective, it is not sufficient to promote the production of new knowledge (e.g., by means of R&D subsidies or university education); it is equally necessary to have entrepreneurs who turn this new knowledge into innovative products (subsequently leading to economic growth). If there are only a few entrepreneurs in a knowledge-intensive region, the Swedish or the European paradox (Ejermo and Kander, 2006; Audretsch, 2007a) can emerge, meaning that many commercial opportunities will remain under-exploited while at most there will be a possibility of their being exploited outside the region. In any case, the profits will not flow back to the region in which the knowledge was produced. To prevent this situation from arising, policymakers may want to promote entrepreneurship in their own country or region. This could be achieved through subsidized loans to high-tech entrepreneurs, regulatory exemptions for innovative new start-ups, or tax benefits. However, we believe that simply encouraging more people to become entrepreneurs is not an effective policy. The government should support those entrepreneurs who really take the risk of transforming new knowledge into innovative products and focus less on those entrepreneurs who merely start another shop around the corner[12]. Many start-ups do not fall into the first category but, rather, belong to the latter group (Koellinger, 2008). An alternative strategy for policymakers would be to promote (entrepreneurship) education to increase the number of qualified and risk-taking entrepreneurs; this would be a more long-term approach.

CONCLUDING REMARKS

More research is needed to determine how to identify, attract, and support those entrepreneurs who transform knowledge into innovative products and thereby increase the competiveness of their particular region. Some questions worth investigating include the following: what types of entrepreneurs turn knowledge into new products (young versus experienced entrepreneurs)? How should these entrepreneurs be funded (equity versus debt)? What is the role of technology clusters and government-sponsored technology parks with regard to the relationship between entrepreneurship and innovation performance?

The stagnation of the competitiveness of the European economies is often attributed to their inability to transform new knowledge into commercially viable products. It has been a persistent notion of policymakers that entrepreneurs play a larger role in this transformation than do large corporations. A wave of policies focusing on the promotion of entrepreneurship has followed. The present analysis shows that this notion is justified.

CONTACT: Joern Block; block@ese.eur.nl; (T): +31104081004; (F) +31104089141; Rotterdam School of Economics, Erasmus University Rotterdam, P.O. Box 1738, 3000 DR Rotterdam, the Netherlands.

NOTES

1. The R&D capital approach also takes international effects into account such as those of foreign R&D, import shares, openness and catch-up mechanisms. See Erken et al. (2009).
2. In their overview of the results Van Praag and Versloot (2007) cite several studies where entrepreneurs do not contribute to several measures of innovative performance.
3. The theory starts from the assumption that given constant individual characteristics entrepreneurial decisions are driven by the context, in particular by the knowledge intensity of the context. Hence, entrepreneurship is not just exogenously driven by individual characteristics, behaviours and traits but also by the endogenous response to opportunities created by the context (Audretsch, 2007a).
4. The production of knowledge part is emphasized by Baumol (2002) who represents the Schumpeterian (1934) view that an environment where most of the breakthrough innovation occurs in small firms while most of the improvement on those innovations and wide-scale dissemination occurs in large firms, is an efficient one. See Ortega-Argilés, Vivarelli and Voigt (2009) for a survey of the various roles of small firms in the process of technological change.
5. Extended information is available at http://epp.eurostat.ec.europa.eu/portal/page/portal/science _technology_innovation/data/database (accessed September 7th, 2009).
6. For extended information, please refer to http://data.ondernemerschap.nl (accessed September 7th, 2009).
7. For extended information, please For detailed information of the CIS, please refer to http://epp.eurostat.ec.europa.eu/portal/page/portal/microdata/cis/publications (accessed September 7th, 2009) refer to http://stats.oecd.org/wbos/index.aspx?r=582080 (accessed September 7th, 2009).
8. For the NACE codes, see http://stats.oecd.org/glossary/detail.asp?ID=1713 (accessed September 7th, 2009).
9. The countries are Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom.
10. Consider the following illustrating example: firm A discloses new knowledge (e.g., through filing a patent). Firm B applies this new knowledge to create a product that is similar to the

product idea of firm A (which then leads to an imitative product). Firm C, however, uses this new knowledge to create a product that is new to both firm A and firm B (which then leads to an innovative product).

11. A different mechanism is suggested by Audretsch, Boente and Keilbach (2008) where innovation efforts are assumed to generate technical knowledge and entrepreneurship capital while the latter two are assumed to lead to economic growth.

12. See also Shane (2009) who discusses at length why simply encouraging more people to become entrepreneurs is a bad public policy.

REFERENCES

Acs, Z.J., Anselin, L., Varga, A. 2002. Patents and innovation counts as measures of regional production of new knowledge. Research Policy 31(7): 1069-1085.

Acs, Z.J., Braunerhjelm, P., Audretsch, D.B., Carlsson, B. 2005. The knowledge filter and entrepreneurship in endogenous growth. Papers on Entrepreneurship, Growth and Public Policy no. 0508, Jena, Germany.

Acs, Z.J., Braunerhjelm, P., Audretsch, D.B., Carlsson, B. 2009. The knowledge spillover theory of entrepreneurship. Small Business Economics 32(1): 15-30.

Arundel, A. 2001. The relative effectiveness of patents and secrecy for appropriation. Research Policy 30(4): 611-624.

Audretsch, D.B. 1995. Innovation and industry evolution. Cambridge (MA): MIT Press.

Audretsch, D.B. 2007a. Entrepreneurship capital and economic growth. Oxford Review of Economic Policy 23(1): 63-78.

Audretsch, D.B. 2007b. The Entrepreneurial Society. Oxford: Oxford University Press.

Audretsch, D., Boente, W., Keilbach, M.C. 2008. Entrepreneurship capital and its impact on knowledge diffusion and economic performance. Journal of Business Venturing 23(6): 687-698.

Audretsch, D.B., Feldman, M.P. 1996. R&D spillovers and the geography of innovation and production. American Economic Review 86(3): 630-640.

Audretsch, DB., Lehmann, E.E. 2005. Does the knowledge spillover theory hold for regions? Research Policy 34(8): 1191-1202.

Audretsch, D.B., Lehmann, E.E., Warning, S. 2005. University spillovers and new firm location. Research Policy 34(7): 1113-1122.

Audretsch, D.B, Keilbach, M.C. 2004. Entrepreneurship capital and economic performance. Regional Studies 38(8): 949-959.

Audretsch, D.B., Keilbach, M.C. 2007. The theory of knowledge spillover entrepreneurship. Journal of Management Studies 44(7): 1242-1254.

Audretsch, D.B., Keilbach, M.C. 2008. Resolving the knowledge paradox: knowledge-spillover entrepreneurship and economic growth. Research Policy 37(10): 1697-1705.

Audretsch, D.B., Thurik, A.R. 2001. What is new about the new economy: sources of growth in the managed and entrepreneurial economies. Industrial and Corporate Change 10(1): 267-315.

Baumol, W.J. 2002. The free market innovation machine: analyzing the growth miracle of capitalism. Princeton: Princeton University Press.

Benz, M., Frey, B. 2008. Being independent is a great thing: subjective evaluations of self-employment and hierarchy, Economica 75(298): 362-383.

Braunerhjelm, P. 2008. Entrepreneurship, knowledge and economic growth. Foundations and Trends in Entrepreneurship 4(5), 451-533.

Breusch, T.S., Pagan, A.R. 1980. The Lagrange multiplier test and its application to model specification in econometrics. Review of Economic Studies 47(1): 239-253.

Breschi, S., Lissoni, F. 2001. Knowledge spillovers and local innovation systems: a critical survey. Industrial and Corporate Change 10(4): 975-1005.

Brockhaus, R.H. 1980. Risk taking propensity of entrepreneurs. Academy of Management Journal 23(3): 509-520.

Bottazzi, L., Peri, G. 2003. Innovation and spillovers in regions: evidence from European patent data. European Economic Review 47(4): 687-710.

Carree, M.A., Stel, A., Thurik, R., Wennekers, S. 2002. Economic development and business ownership: an analysis using data of 23 OECD countries in the period 1976-1996. Small Business Economics 19(3): 271-290.

Carree, M.A., Thurik, A.R. 2003. The impact of entrepreneurship on economic growth. In: Z.J. Acs and D.B. Audretsch (eds.), Handbook of Entrepreneurship Research, Kluwer Academic Publishers, Boston: 437-471.

Cohen, W.M., Levinthal, D.A. 1989. Innovation and learning: the two faces of R&D. The Economic Journal 99(397): 569-596.

Cohen, W.M., Levinthal, D.A. 1990. Absorptive capacity: a new perspective on learning and innovation. Administrative Science Quarterly 35(1): 128-152.

Ejermo, O., Kander, A. 2006. The Swedish paradox. CIRCLE Electronic Working Paper Series 2006/01, CIRCLE, Lund, Sweden.

Erken, H., Donselaar, P., Thurik, A.R. 2009. Total factor productivity and the role of entrepreneurship. Tinbergen Institute discussion papers TI09-034/3. Rotterdam, Netherlands.

Furman, J.L., Porter, M.E., Stern, S. 2002. The determinants of national innovative capacity. Research Policy 31(6): 899-933.

Glaeser, E.L., Kallal, H.D., Scheinkman, J.A., Shleifer, A. 1992. Growth in cities. Journal of Political Economy 100(6): 1126-1152.

Griliches, Z. 1998. R&D and productivity: the econometric evidence. University of Chicago Press, Chicago.

Griliches, Z. 2000. R&D, education, and productivity. A retrospective. Harvard University Press, Cambridge (MA).

Hausman, J.A. 1978. Specification tests in econometrics. Econometrica 46(6): 1251-1271.

Hauser, J., Zettelmeyer, F. 1997. Metrics to evaluate R, D & E. Research Technology Management, 40 (4): 32-38.

Hoelzl, W. 2009. Is the R&D behaviour of fast-growing SMEs different? Evidence from CIS III data for 16 countries. Small Business Economics 33(1): 59-75.

Iammarino, S., McCann, P. 2006. The structure and evolution of industrial clusters: Transactions, technology and knowledge spillovers. Research Policy 35(7): 1018-1036.

Jaffe, A.B., Trajtenberg, M., Henderson, R. 1993. Geographic localization of knowledge spillovers as evidenced by patent citations. Quarterly Journal of Economics 108(3): 577-598.

Jaffe, A.B., Trajtenberg, M., Fogarty, M.S. 2000. Knowledge spillovers and patent citations: evidence from a survey of inventors. American Economic Review 90(2): 215-218.

Jovanovic, B. 1982. Selection and the evolution of industry. Econometrica, 50(3): 649-670.

Kihlstrom, R.E., Laffont, J.J. 1979. A general equilibrium entrepreneurial theory of firm formation based on risk aversion. Journal of Political Economy 1(4): 719-748.

Koellinger, P. 2008. Why are some entrepreneurs more innovative than others? Small Business Economics 31(1): 21-37.

Link, A. N., Scott, J.T. 2005. Opening the ivory tower's door: an analysis of the determinants of the formation of U.S. university spin-off companies. Research Policy 34(7): 1106-1112.

Lucas, R.E. 1988. On the mechanics of economic development. Journal of Monetary Economics 22(1): 3-42.

Lucas, R.E. 1993. Making a miracle. Econometrica 61(2): 251-272.

Mairesse, J., Mohnen, P. 2002. Accounting for innovation and measuring innovativeness: an illustrative framework and an application. American Economic Review 92: 226-231.

Mairesse, J., Mohnen, P. 2004. The importance of R&D for innovation: a reassessment using French survey data. NBER Working Paper 10897.

Mansfield, E. 1965. Rates of return from industrial research and development. American Economic Review, 55(1/2), 310-322.

McClelland, D.C. 1961. The achieving society. Princeton: Van Nostrandt.

Mueller, P. 2006. Exploring the knowledge filter: how entrepreneurship and university-industry relationships drive economic growth. Research Policy 35(10): 1499-1508.

Ortega-Argilés, R., Vivarelli, M., Voigt, P. 2009. R&D in SMEs: a paradox? Small Business Economics 33(1): 3-11.

Parker, S. 2004. The economics of self-employment and entrepreneurship. Cambridge: Cambridge University Press.

Romer, P.M. 1986. Increasing returns and long-run growth. Journal of Political Economy 94(5): 1002-1037.

Romer, P.M. 1990. Endogenous technical change. Journal of Political Economy 98(5): S71-S102.

Schere, J.C. 1982. Tolerance of ambiguity as a discriminating variable between entrepreneurs and managers. Academy of Management Proceedings: 404-408.

Schumpeter, J. A. 1934. The theory of economic development. Cambridge, US: Harvard University Press.

Shane, S., Venkataraman, S. 2000. The promise of entrepreneurship as a field of research. Academy of Management Review 25(1): 217-226.

Shane, S. 2009. Why encouraging more people to become entrepreneurs is a bad public policy. Small Business Economics 33(2): 141-149.

Timmons, J.A. 1976. Characteristics and role demands of entrepreneurship. American Journal of Small Business 3: 5-17.

Van Praag, C.M., Versloot, P.H. 2007. What is the value of entrepreneurship? A review of recent research. Small Business Economics 29(4): 351-382.

Van Stel, A. 2005. COMPENDIA: harmonizing business ownership data across countries and over time. The International Entrepreneurship and Management Journal 1(1): 105-123.

Vandenbussche, J., Aghion, P., Meghir, C. 2006. Growth, distance to frontier and composition of human capital. Journal of Economic Growth 11(2): 97-127.

Wiggins, S. 1995 Entrepreneurial enterprises, endogenous ownership, and the limits to firm size. Economic Inquiry, 33(1): 54-69.

Wooldridge, J.M. 2002. Econometric analysis of cross section and panel data. Cambridge, MA: The MIT Press.

Note: the remaining tables mentioned in the text are displayed in a full paper version but (due to size limitations) not in the BCERC version.

Table 4. Pooled OLS regressions on *innovation performance*

Independent variables	**Model I** Coeff. (SE)	**Model II** Coeff. (SE)	**Model III** Coeff. (SE)	**Model IV** Coeff. (SE)
Macro-economic variables				
ln(GDP)	0.28 (0.49)	-0.21 (0.67)	-0.34 (0.61)	-0.70 (0.66)
ln(GDP per capita)	-3.17 (1.57)†	-6.54 (2.29)**	-6.69 (2.19)**	-7.38 (2.25)**
Rate of knowledge-intensive firms		0.27 (0.14)†	0.31 (0.12)*	-0.33 (0.24)
Entrepreneurship rate			0.09 (0.20)	-0.38 (0.19) †
Rate of knowledge-intensive firms X entrepreneurship rate				0.07 (0.03)**
Year dummies (reference year: 1998)				
Year 2000	1.94 (1.45)	2.94 (1.76)	3.01 (1.78)	3.25 (1.70)†
Year 2004	1.70 (1.08)	2.81 (1.50)†	2.91 (1.39)*	3.13 (1.29)*
Year 2006	2.64 (0.79)**	3.98 (1.33)**	4.16 (1.12)**	3.13 (1.29)*
Constant	34.83† (17.98)	71.11 * (27.33)	72.77* (26.97)	88.43** (26.70)
F-value	5.31 **	4.67 **	4.60 **	6.53 **
p-value Breusch-Pagan test for random effects	0.01	0.05	0.10	0.14
R^2	0.13	0.22	0.22	0.29
R^2 (without year dummies)	0.07	0.11	0.11	0.17
Adjusted R^2	0.04	0.12	0.11	0.18
N observations (countries)	57 (21)	57 (21)	57 (21)	57 (21)

SE=robust and clustered standard errors; Coeff.=regression coefficient
Data sources: CIS, COMPENDIA, and OECD Economic Outlook Database
†: at 0.1 significance level; *: at 0.05 significance level; **: at 0.01 significance level; two-tailed tests

We also calculated the effect of a time trend variable with year 1998=1, year 2000=2, year 2004=3, and year 2006=4. The coefficients (SE) are as follows: Model I: β=0.759 (0.31)*; Model II: β=1.13 (0.42) *; Model III: β=1.18 (0.33) **; Model IV: β=1.22 (0.32) **.

Table 5. Pooled OLS regressions on *imitation performance*

Independent variables	**Model I** Coeff. (SE)	**Model II** Coeff. (SE)	**Model III** Coeff. (SE)	**Model IV** Coeff. (SE)
Macro-economic variables				
ln(GDP)	1.91 (1.29)	0.98 (0.94)	1.40 (1.20)	1.52 (1.42)
ln(GDP per capita)	2.50 (2.12)	-3.89 (2.34)	-3.41 (2.04)	-3.19 (2.10)
Rate of knowledge-intensive firms		0.51 (0.18)*	0.39 (0.13)**	0.59 (0.48)
Entrepreneurship rate			-0.29 (0.19)	-0.14 (0.23)
Rate of knowledge-intensive firms X entrepreneurship rate				-0.02 (0.05)
Year dummies (reference year: 1998)				
Year 2000	-0.95 (1.92)	0.96 (2.02)	0.73 (1.86)	0.65 (1.90)
Year 2004	-9.53 (2.04)**	-7.44 (1.71)**	-7.78 (1.71)**	-7.85 (1.75)**
Year 2006	-10.43 (2.28)**	-7.88 (2.14)**	-8.48 (1.91)**	-8.53 (1.95)**
Constant	-30.58 (32.95)	38.23 (24.64)	32.81 (23.74)	27.82 (29.92)
F-value	6.51 **	6.93 **	6.13 **	6.84 **
p-value Breusch-Pagan test for random effects	0.01	0.11	0.05	0.04
R^2	0.50	0.59	0.60	0.61
R^2 (without year dummies)	0.15	0.33	0.33	0.33
Adjusted R^2	0.45	0.54	0.55	0.54
N observations (countries)[a]	57 (21)	57 (21)	57 (21)	57 (21)

SE=robust and clustered standard errors; Coeff.=regression coefficient
Data sources: CIS, COMPENDIA, and OECD Economic Outlook Database
[†] : at 0.1 significance level; *: at 0.05 significance level; **: at 0.01 significance level; two-tailed tests

We also calculated the effect of a time trend variable with year 1998=1, year 2000=2, year 2004=3, and year 2006=4. The coefficients (SE) are as follows: Model I: β=-4.07 (0.77)**; Model II: β=-3.37 (0.66)**; Model III: β=-3.57 (0.66) **; Model IV: β=-3.71 (0.71) **.