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Entrepreneurship, Agglomeration and Technological Change

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Abstract:
Technological change is a central element in macroeconomic growth explanation. Endogenous growth models take a revolutionary step towards better understanding the economic growth process by deriving technological change from profit-motivated individual behavior. In endogenous growth theory knowledge spillovers play a fundamental role in the determination of the rate of technological progress. As such the efficiency of transmitting knowledge into economic applications is a crucial factor in explaining macroeconomic growth. Endogenous growth models take this factor exogenous. We argue that variations across countries in entrepreneurship and the spatial structure of economic activities could potentially be the source of different efficiencies in knowledge spillovers and ultimately in economic growth. We develop an empirical model to test both the entrepreneurship and the geography effects on knowledge spillovers. To date the only international data that are collected on the basis of exactly the same principles in each country are the Global Entrepreneurship Monitor (GEM) data. We use the 2001 GEM cross-country data to measure the level of entrepreneurship in each particular economy. For this purpose we apply the TEA index developed within the framework of the GEM project and calculated for each country participating in this international research. Additionally, data on employment, production, patent applications, public and private R&D expenditures originating from different international and national sources are applied in the paper.

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1. Introduction

The story of the entrepreneurial process often told in the literature is one of the entrepreneur recognizing and acting on an unexploited opportunity. This opportunity frequently, but not always, exists in a crowded space of research universities, networks and venture capitalists. This so called Silicon Valley story has been told in the context of other high technology agglomerations including Seattle WA, Austin TE, Boston MA, and Washington D.C. It also has its international counter parts in Bangalore India, London UK and Baden Würtenberg Germany. It is further recognized that the entrepreneurial process should lead to economic growth with the creation of successful growing companies like Microsoft, Intel and Sun Microsystems among others. While there is some evidence that entrepreneurship and agglomerations play a role in economic growth this has not been worked out theoretically (Bresnahan, Gambardella and Saxenian, 2001).

Paul Romer has developed a theory that explains economic growth through the accumulation of technological knowledge. The economy grows endogenously through the accumulation and spillover of knowledge. The seminal contribution of Romer (1986, 1990) to the literature on economic growth was to endogenize technological change within an economy, thereby providing a more realistic explanation of economic growth than the neoclassical theory that focuses purely on the role of investment in physical capital or increases in the supply of labor. However, the theory offers no insight into what role if any entrepreneurship and agglomeration play in economic growth. In other words, it does not answer the question, “What is the role of entrepreneurship and agglomeration in technological change at the national level?”

The answers to this question can be pursued through the lens of the “new” economic geography and the modern theory of entrepreneurship. The distinguishing characteristic of the new economic geography literature is that it studies the economy within a framework that integrates space into general equilibrium theory (Krugman, 1991). One aspect of economic geography is agglomeration of knowledge. The new economic geography literature over the past decade has tried to explain the development and the role of geographic structures in economics and one of the important questions is related to the role of agglomeration in technological change and ultimately in macroeconomic growth.

The recent literature on entrepreneurship has shifted the emphasis in entrepreneurship from cultural and psychological traits to the exploitation of technological opportunity by profit seeking agents (Acs and Audretsch, 2003). However, we are a long way from having a formal theory of entrepreneurship. Entrepreneurship research has recently become interested in the relationship between entrepreneurship and economic growth. If entrepreneurs play an important role in the exploitation of technological opportunity the impact of entrepreneurship on growth becomes an important research question. This is one of the central questions pursued by the GEM program.

Both the relationship between geography and technological change and between entrepreneurship and technological change is interesting because these lines of research may prove fruitful in better explaining economic growth. However, both approaches have severe limitations. While there have been several attempts to model endogenous growth theory and endogenously generated spatial structures this work is still in its infancy as the answering of the question is hampered because there is no space in growth theory and (at least until the very recent attempts) the role of spatial structure in technological change has been missing in the new economic geography.

The modeling of entrepreneurship and economic growth is in a similar position. Again this line of research is hampered because there is no entrepreneurship in growth theory and the role of technological change in entrepreneurship is not well worked out. The attempt to come up with useful and reliable measures of entrepreneurship has also been a daunting challenge.

Both economic geography and entrepreneurship can shed light on economic growth because the process by which endogenous technological change actually takes place has not been fully explained by the new growth theory. The purpose of this paper is to develop an empirical framework to test the importance of entrepreneurship and agglomeration effects on economic growth based on the Romerian (1990) model of endogenous technological change. This paper presents the first empirical test of the impact of technological entrepreneurship and agglomeration effects on the spillover of new knowledge in economic growth. The model allows us to directly test the relationship between technological change and technological opportunity as it is conditioned by entrepreneurship and agglomeration effects while controlling for spillover effects from the stock of knowledge.

We make three original contributions. First, we extend the Romer (1990) model to account for entrepreneurship and agglomeration effects in the spillover of knowledge. Second, we develop a novel empirical framework to test this relationship. Third, we use a new and novel data set from the Global Entrepreneurship Monitor (GEM) project to test the effects of entrepreneurship on knowledge spillovers in the European Union. Section 2 examines the relationship between the new economic geography, knowledge spillovers and economic growth and the relationship between entrepreneurship, knowledge spillovers and economic growth. Section 3 extends the basic Romer model, develops the empirical specification and presents the data. Section 4 has the results and the final section has the conclusions. We find significant empirical support for the Romer model, where the coefficient on the stock of knowledge is significant but less then one. We find weak support for the hypothesis that both agglomeration effects and entrepreneurship facilitate the knowledge spillover mechanism of new knowledge in economic growth.

2. Entrepreneurship and Agglomeration

Technological change is the single most important factor in long-run macroeconomic growth (Solow 1957). In endogenous growth theories the technological element of the growth process is directly modeled within the economic system as a result of profit motivated choices of economic agents. Recently published findings in entrepreneurship research and in the studies of the geography of innovation and the new economic geography suggest that the extent to which a country is “entrepreneurial” and its economic system is spatially agglomerated could be a factor that explains technological change. In this section we outline these literatures from the economic growth perspective.

2.1 Entrepreneurship and technological change

In their efforts to define a distinctive domain for the field of entrepreneurship researchers have recently shifted attention way from equilibrium approaches, which focus on identifying those people in society who prefer to become entrepreneurs, towards the individual-opportunity nexus (Shane and Venkataraman, 2000). This new focus has been prompted by the need for scholars to explain the existence of opportunity, the identification and discovery of opportunity and the process of exploitation (Shane 2003). Any explanation of entrepreneurial opportunity requires a discussion of where these opportunities come from and from the point of technological change it becomes important to identify the source of technological opportunity.

The origins of the discussion about the existence of opportunity can be traced to Joseph Schumpeter (1934). Schumpeter believed that the existence of opportunity required the introduction of new knowledge not just differentiated access to existing knowledge (Kirzner, 1973). One source of new knowledge came from changes in technology. These technological opportunities are innovative and break away from existing knowledge. Opportunity therefore comes in part from the research and development (R&D) process that takes place in society. Technological change is an important source of entrepreneurial opportunity because it makes it possible for people to allocate resources in different and potentially more productive ways (Casson, 1995).

However, as was pointed out by Arrow (1974) the link between knowledge and economic knowledge is now well understood. The central problem is a gap in our understanding between technological change and the market that come into existence based on that innovation—a gap in our understanding of economics that is filled by the notion of entrepreneurial opportunity. An entrepreneurial opportunity consists of a set of ideas, beliefs and actions that enable the creation of future goods and services in the absence of current markets for them.

If technological opportunity is in part created by the production of new knowledge how is this opportunity discovered? One way in which people discover technological opportunity is through knowledge spillovers. Entrepreneurial discovery is in fact a process of knowledge spillover where knowledge is a non-rival good. Once entrepreneurs discover new opportunities, which are only partially excludable, they have the chance to exploit the opportunity. While most R&D is carried out in large firms and universities it does not mean that the same individuals that discover the opportunity them will carry out the exploitation. In fact, because knowledge spills over, one person may discover an opportunity and another may exploit it.

The uncertainty inherent in new economic knowledge, combined with asymmetries between the agent possessing that knowledge and the decision making of the incumbent organization with respect to its expected value that potentially leads to a gap between the valuation of the knowledge. This initial condition of not just uncertainty but greater degree of uncertainty vis-à-vis incumbent enterprises in the industry is captured in the theory of firm selection and industry evolution proposed by Jovanovic (1982). An implication of the theory of firm selection is that new firms may begin at a small scale of output, and then if merited by subsequent performance expand. What emerges from the new evolutionary theories and empirical evidence on the role of new firms is that markets re in motion, with a lot of new firm entering the industry and lots of firms leaving (Audretsch, 1995). The empirical evidence supports such an evolutionary view of the role of new firm (Sutton, 1997; Caves, 1998).

The empirical evidence supports the argument that technological change is a source of entrepreneurial opportunity. The evidence is indirect since we cannot measure the existence of opportunity. Two important proxy measures of the existence of entrepreneurial opportunity are the tendency of people to engage in self-employment and the tendency of people to start new firms. Acs and Audretsch (1989) found that small entrepreneurial firms play a key role in generating innovations, at least in some industries. Blau (1987) examined self-employment rates in the United States over a two-decade period and found that an increase in the rate of technological change led to an increase in the self-employment rate. Shane (1996) looked at the number of organizations per capita from 1899 to 1988 and found that the rate of technological change, measured as the annual number of new patents issued, had a positive effect on the number of organizations per capita in the economy in the subsequent year.

While the relationship between technological change and opportunity cannot be measured directly several authors have tried to measure the relationship between entrepreneurship and employment growth. Acs and Armington (2003) found that differences in the level of entrepreneurial activity and the extent of human capital are positively associated with variation in growth rates. Holtz-Eakin and Kao (2003) using a rich panel of state-level date to quantify the relationship between productivity growth and entrepreneurship found that the effect of startups on productivity is quite persistent. These results are consistent with Audretsch and Keilbach (2003) who estimate a production function model for German regions based on start-up data from the 1990s. The empirical evidence seems to suggest that entrepreneurship plays an important role in the discovery and exploitation of technological opportunity through knowledge spillovers. These theories suggest that the existence of entrepreneurship should facilitate knowledge spillovers and lead to higher economic growth.

Theories of entrepreneurship and growth are still relatively new even though the entrepreneurship literature does recognizes that R&D is an important source of technological opportunity (for a survey of the literature see Carree and Thurik, 2003**.** The process by which knowledge spills over from the firm producing it for use by a third-party firm is exogenous in the model proposed by Romer (1990). The emphasis was on the influence of knowledge spillovers on technological change without specifying *why* and *how* new knowledge spills over. Yet, the critical issue in modeling knowledge-based growth rests on the spillover of knowledge. This was to some extent remedied by the neo-Schumpeterian models of endogenous growth (Schmitz 1989, Segerstrom, Anant and Dinopoulos 1990, Segerstrom 1991, Aghion and Howitt 1992, Cheng and Dinopoulos 1993). These neo-Schumpeterian models design entrepreneurship as an R&D race where a fraction of R&D will turn into successful innovations.

While this implies a step forward, the essence of the Schumpeterian entrepreneur is missed. The innovation process stretches far beyond R&D races that predominantly involve large incumbents and concern quality improvements of existing goods. As pointed out by Schumpeter (1947) "the inventor produces ideas, the entrepreneur 'gets things done' ….. an idea or scientific principle is not, by itself, of any importance for economic practice." Indeed, the Schumpeterian entrepreneur, by and large, remains absent in those models. Acs, et al (2004) develops a model of how the "pure" Schumpeterian entrepreneur influences the spillover of non-codified tacit knowledge and how knowledge production can be more or less smoothly filtered and substantiated into economic growth. The paper develops a theoretical model that introduces a filter between new knowledge and technological change and identifies entrepreneurship as a mechanism that reduces the knowledge filter. In this model the value of the parameter on knowledge production falls between zero and one.

2.2 Agglomeration and Technological Change

As long as the knowledge necessary for technological change is codified (i.e., it can be studied in written forms either in professional journals and books or in patent documentations) the access to it is essentially not constrained by spatial distance: among other means libraries or the Internet can facilitate the flow of that knowledge to the interested user no matter where the user actually locates. However, in case knowledge is not codified for several reasons such as it is not yet completely developed or it is so practical that it can only be transmitted while knowledge is actually being applied the flow of it can only be facilitated by personal interactions. Thus for the transmission of tacit knowledge (Polanyi 1967) spatial proximity of knowledge owners and potential users appears to be critical.

It should not happen by accident only that several firms move their research facilities to certain geographic areas where significant amounts of related knowledge has already been accumulated in order to get easier access to that knowledge. Knowledge spillovers from other (industrial or academic) research facilities can be channeled via different means such as a web of social connections, the local labor market of scientists and engineers or by different types of consultancy relations between universities and private firms.

A large body of recently emerged literature has been studying the spatial extent of knowledge spillovers with a particular attention to spillovers from industrial and academic research. At different levels of spatial aggregation (such as states, metropolitan areas, counties) in different countries (e.g., the US, France, Germany, Italy, Austria) and with the application of different econometric methodologies (e.g., various spatial or a-spatial methods) many of these studies conclude that geographical proximity to the knowledge source significantly amplifies spillovers between research and innovating firms. It is shown for instance in Glaeser, Kallal, Scheinkman and Shleifer (1992) that economic growth in US cities is directly related to localized interindustry knowledge flows. Also, strong evidence is provided both for the US (Jaffe, Trajtenberg and Henderson 1993, Varga 1998, Acs, Anselin and Varga 2002) and for Europe (e.g., Autant-Bernard 2001, Fischer and Varga 2003) that knowledge flows are bounded within a relatively narrow geographical range. Although certain industrial differences exists (such as for innovation in the microelectronics, instruments of biotechnology sectors proximity is more significant than for new technology development in the chemicals or the machinery industries) the hypothesis that spatial proximity is an important factor in innovation is strongly supported in the literature.

However the cases of some localities where significant research competencies have been developed without the parallel emergence of related industries (such as in Baltimore in the mid-1990s where highly developed local academic research but a weak related industry presence is experienced by Feldman 1994) suggest that proximity is a necessary but not sufficient condition for successful knowledge transfers: the magnitude of localized knowledge spillovers from research is also influenced by agglomeration. In Varga (2000, 2001) empirical evidence is provided that the spillover impact in knowledge production is positively related to the size of the region. Different types of agglomeration effects are at work to explain this phenomenon. Larger regions inhabit more firms connected by richer network linkages and as such the same knowledge generated by research in the area spills over to potentially more applications. Larger regions also offer a wider selection of producer services essential in technological innovation (e.g., information technology, legal, marketing services) contributing to a larger number of new technologies developed from the same knowledge base generated by (public and private) research in the area.

Agglomeration of research, industry and the producer services sector is a significant factor in technological change as it facilitates knowledge spillovers. How do those agglomerations emerge in space? The new economic geography literature provides a general equilibrium framework where spatial economic structure is endogenously determined simultaneously with equilibrium in goods and factor markets (Krugman 1991, Fujita, Krugman and Venables 1999). This is a real breakthrough in economics given that before the appearance of the new economic geography no any school of economics since von Thünen' *Der Isolierte Staat* in the early nineteenth century had been able to build an economic model where the development of spatial structure is treated endogenously within a general equilibrium framework (Samuelson 1983). It is right to say that the new economic geography presents "a new recipe with old ingredients" as many of the elements of the system (such as that the equilibrium spatial structure results from the interplay of centripetal forces (e.g., increasing returns to scale or agglomeration economies) and centrifugal forces (e.g., transportation costs) or that regional growth can best be explained as a cumulative process enforced by agglomeration economies) had already been developed in regional economics and in the "traditional" economic geography (Ottaviano and Thisse 2004).

The most recent models in the new economic geography incorporate the effects of knowledge spillovers on the formation of spatial economic structure as well as they provide the first attempts to explicitly integrate the two "new" schools of economics: the endogenous theory of economic growth and the new economic geography (Fujita and Thisse 2002, Baldwin, Forslid, Martin, Ottaviano and Robert-Nicoud 2003). The need for the ingration of the two schools is clear if one takes into account that if agglomeration facilitates knowledge spillovers (according to the new economic geography) and knowledge spillovers determine per-capita GDP growth (according to the endogenous growth theory) then it is not an unrealistic assumption that spatial economic structure affects macroeconomic growth.

Unfortunately, empirical investigations in the area of agglomeration and macroeconomic growth are still relatively uncommon in the literature. The very few exceptions include Ciccone and Hall (1996), Ciccone (2002) and Varga and Schalk (2004). The following section presents the empirical modeling framework to integrate entrepreneurship and agglomeration into the explanation of technological change (and implicitly into the explanation of macroeconomic growth).

3. The empirical modeling framework

Our framework for empirical investigations is based on the Romer (1990) model of aggregate knowledge production as extended by Jones (1995). One of the most original contributions of Romer (1990) is the separation of economically useful scientific-technological knowledge into two parts. The total set of knowledge consists of the subsets of non-rival, partially excludable knowledge elements that can practically be considered as public goods and the rival, excludable elements of knowledge. Codified knowledge published in books, scientific papers or in patent documentations belongs to the first group. This knowledge is non-rival since eventually it can be used by several actors at the same time and many times historically. On the other hand it is only partially excludable since only the right of applying a technology for the production of a particular good can be guaranteed by patenting while the same technology can spill over to further potential economic applications as others can study the patent documentation. Rival, excludable knowledge elements include the personalized (tacit) knowledge including particular experiences, insights developed and owned by the researchers themselves.

Equation (1) presents the manner the two types of knowledge interact in the production of economically useful new technological knowledge.

$$(1) \qquad \text{Å} = \delta\, H_A^{\lambda}\, A^{\varphi},$$

where H_A stands for the number of researchers working on knowledge production in the business sector, A is the total stock of technological knowledge available at a certain point in time whereas Å is the change in technological knowledge resulted from private efforts to invest in research and development. δ, λ and φ are parameters. The particular functional form of knowledge production in (1) is explained by the assumption of Romer (1990) that the efficiency of knowledge production is enhanced by the historically developed stock of scientific-technological knowledge. Even the same number of researchers becomes more productive if A increases over time. A is assumed to be perfectly accessible by everyone working in the research sector. However, as follows from the modification of Jones (1995) spillovers from the stock of codified knowledge might not be perfect. Hence the value of the aggregate codified knowledge spillovers parameter φ should be between 0 and 1. Equation (1) plays a central role in economic growth explanation since on the steady state growth path the rate of per capita GDP growth equals the rate of technological change (Å/A).

However, not only codified but also non-codified, tacit knowledge can spill over as detailed in the previous section. The value of λ in (1) reflects the extent to which tacit knowledge spills over within the research sector. Based on the literature we assume that these spillovers are influenced largely by the agglomeration of researchers as well as by the level of entrepreneurial activity in the country.

To empirically investigate the extent to which entrepreneurship and agglomeration affect knowledge spillovers we create an empirical model in which we endogenize the parameter λ in (1).

(2) $\log(NK) = \delta + \lambda\log(H) + \varphi\log(A) + \varepsilon$

(3) $\lambda = (\beta_1 + \beta_2\log(ENTR) + \beta_3\log(AGGL))$

where NK stands for new knowledge (i.e., the change in A), ENTR is entrepreneurship, AGGL is agglomeration, A is the set of publicly available scientific-technological knowledge and ε is stochastic error term. Implementation of (3) into (2) results in the following estimated equation:

(4) $\log(NK) = \delta + \beta_1\log(H) + \beta_2\log(ENTR)\log(H) + \beta_3\log(AGGL)\log(H) + \varphi\log(A) + \varepsilon$

In (4) the estimated values of the parameters β_2 and β_3 measure the extent to which research interacted with entrepreneurship and agglomeration contributes to knowledge creation.

In the estimation of (4) the units of observation are selected industrial sectors in European countries for the year 2001[1]. The selection of countries and sectors is determined by data availability. NK is measured by the number of patent applications, while R&D expenditures in Euro measure H. A is operationalized by the total number of available patents in all the sectors in the country (i.e., the total number of patents granted by inventors of the country in the last 20 years). The source of patent data is

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[1] Industrial sectors include Chemistry and Pharmaceuticals, Computers and Office Machines, Electrical Machinery, Electronics, Instruments, Other Machinery, Transportation Vehicles. The following European countries are included: Belgium, Germany, France, Hungary, Ireland, Italy, Poland, Spain and the United Kingdom.

the OECD patent database. International patent classification (IPC) classes are assigned to industrial classes (ISIC Rev. 2) by the application of the MERIT concordance table developed by Verspagen, Moergastel and Slabbers (1994). R&D expenditures data are provided by Eurostat.

AGGL is measured by the Spatial Herfindahl index, that is the sum of squared aggregate regional employment of the country[2]. Regional employment data are provided by Eurostat. ENTR is empirically measured by the total entrepreneurial activity (TEA) index developed within the framework of the Global Entrepreneurship Monitor (GEM) project. The intent of GEMs is to systematically assess two things: the level of start-up activity or the prevalence of nascent firms and the prevalence of new or young firms that have survived the start-up phase.

First, start-up activity is measured by the proportion of the adult population (18-64 years of age) in each country that is currently engaged in the process of creating a nascent business. Second the proportion of adults in each country who are involved in operating a business that is less than 42 months old measures the presence of new firms. The distinction between nascent and new firms is made in order to determine the relationship of each to national economic growth. For both measures, the research focus is on entrepreneurial activity in which the individual involved have a direct but not necessarily full, ownership interest in the business. There are numerous ways to measure entrepreneurial activity. One important distinction is between opportunity-based entrepreneurial activity and necessity-based entrepreneurial activity. Opportunity entrepreneurship represents the voluntary nature of participation and necessity reflecting the individual’s perception that such

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[2] With the exception of Belgium and the UK where the highest level of data aggregation is NUTS 2 for the rest of the countries the Spatial Herfindahl index is calculated using NUTS 3 level aggregated employment data.

actions presented the best option available for employment but not necessarily the preferred option. Opportunity entrepreneurship differs from necessity by sector of industry and with respect to growth aspirations. Opportunity entrepreneurs expect their ventures to produce more high growth firms and provide more new jobs. The 16 European Union countries in 2001 had an average prevalence rate of about 8 percent. This was below the North American average of 11.3 percent and the developing countries averages of 14.5 percent (Reynolds, et. al., 2001).

In empirically estimating equation (4) two issues should get particular attention: multicollinearity (because H appears three times in the equation) and heteroscedasticity (since the expected heterogeneity of the country-industry dataset).

4. Empirical Results

Table 1 presents empirical estimation results for equation (4). The equation is estimated by OLS. Standard errors are based on the White heteroskedasticity consistent covariance matrix estimator which provides correct estimates of the coefficient covariances in the presence of heteroskedasticity of unknown form (White 1980).

In Model 1 the estimated parameter of log(H) is highly significant. The logarithm of R&D expenditures explains 75 percent of the variations in the logarithm of patent applications at the country-industry level. The additional effect of log(A) where A is measured by the aggregate stock of available patents is considerable: it improves regression fit by 24 percent. Both coefficients are highly significant indicating that the original Romer (1990) equation captures well the main factors in technological change.

Extending Model 2 by the inclusion of the interaction term Log(H)*Log(AGGL) improves regression fit only slightly while the estimated parameter is not significant. This does not correspond to findings in the empirical knowledge spillovers literature or in expectations based on theoretical results in the new economic geography. It could perhaps be the outcome of the shortcomings of the measurement applied (i.e., the Spatial Herfindahl index is not sensitive to differences in the relative geographical positions of regions within a country). Technical constraints could not make it possible for us to improve on this agglomeration measure. However we also assumed that perhaps an outlier observation, Germany might cause the unexpected result. A closer investigation of the Spatial Herfindahl index reveals that Germany is the country where economic activities exhibit an extremely low level of spatial concentration (relative to the rest of the countries in the sample). While the average value of the Spatial Herfindahl index in the sample is 0.06, the corresponding value for Germany is only 0.007. To account for the "Germany-effect" in agglomeration a dummy variable (DUMGER) is included in Model 4. The parameter of DUMGER is marginally significant ($p<0.10$) whereas the interaction term's parameter becomes significant ($p<0.05$).

Table 1. OLS Regression results for Log(Patent applications) for selected industries in selected European countries (N=63, 2001)

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Constant	0.022	-3.175	-3.646	-3.744	-3.97	-3.935
	(0.362)	(0.346)	(0.443)	(0.440)	(0.362)	(0.600)
Log (H)	0.865	0.298	0.397	0.497	0.141	0.343
	(0.063)	(0.061)	(0.085)	(0.101)	(0.106)	(0.121)
Log(H)*Log(AGGL)			0.031	0.063		0.060
			(0.019)	(0.026)		(0.026)
Log(H)*Log(ENTR)					0.096	0.089
					(0.053)	(0.047)
Log(A)		0.723	0.783	0.791	0.748	0.813
		(0.063)	(0.072)	(0.071)	(0.064)	(0.083)
DUMGER				0.714		0.664
				(0.405)		(0.323)
R^2-adj	0.75	0.92	0.93	0.93	0.93	0.93
F-statistic	186	357	246	192	248	159

Note: White heteroscedasticity-consistent estimated standard errors are in parentheses; variables are explained in the text.

In model 5 the separate effect of the interaction term between research workers and opportunity-based entrepreneurial activity Log(H)*Log(ENTR) is shown in the Romerian knowledge production function. The corresponding estimated parameter is marginally significant ($p<0.10$). Model 6 is the final equation. Regression fit increases only slightly as compared to the original Romer equation in Model 2. The effect of research interacted with agglomeration is significant at the 5 percent level while research interacted with entrepreneurship is marginally significant ($p<0.10$). Estimated parameters of the interaction terms, the dummy variable and Log(A) as well as their significance patterns are stable across the models. The coefficient of Log(H) shows the highest variation however its estimated values in the final model and the original Romerian equation do not differ substantially. These observations suggest that multicollinearity is not a serious issue in the model.

The estimated elasticity of technological change with respect to available codified knowledge is less than 1 (0.8) that corresponds to what is suggested by Jones

(1995). The estimated research spillover effect is related to entrepreneurship and agglomeration according to the following equation:

(5) $\lambda = 0.34 + 0.06*Log(AGGL) + 0.09*Log(ENTR)$

What do these results suggest for entrepreneurship? Table 2 shows the coefficients for knowledge spillovers for nine countries with and without the effect of entrepreneurship and agglomeration. As shown in column two agglomeration effects vary considerably from country to country with a high of 0.186 in Ireland to a low of 0.006 in Germany. The TEA also varies from a low of 3.6 percent in Belgium to a high of 9.2 in Ireland. The elasticity of R&D spillovers with respect to new knowledge is 0.30 (Model 2 in Table 1). This number is relatively small with respect to the 0.8 elasticity found for the total stock of knowledge.

One would suspect that entrepreneurship would be able to significantly raise the effect of R&D spillovers from new knowledge. This would especially be true if entrepreneurs played an important role in knowledge spillovers as suggested by the entrepreneurship literature. Column four shows the value of the coefficient of λ extended by entrepreneurship and agglomeration effects. The coefficient varies between 0.27 and 0.38 and is greater than 0.30 in seven countries and smaller in France and Germany. These results are broadly consistent with Michelacci (2003) who found the value of λ (for entrepreneurship only) for the United States varied between 0.24 and 0.48 for the post war period. The last column shown the ration of the extended coefficient divided by the non-extended coefficient. The ratio varies from 0.91 to 1.28. These results suggest two trends. First, in large countries, like France and Germany, we do not have enough entrepreneurship and agglomerations and therefore knowledge spillovers are not strong enough to increase technological change. In Ireland and Hungary, two countries with one very large city in each country the agglomeration effects and entrepreneurship increase knowledge spillovers from the R&D effort. However, both of these countries have followed a model of growth that has relied on large-scale direct foreign investment to foster economic growth over the years (Acs and Szerb, 2004; Varga and Schalk, 2003).

Table 2. Country Coefficients with and without Extension for Entrepreneurship and Agglomeration

	AGGL	ENTR	Coefficient (Mod. 6)	Coefficient (Mod. 2)	Coefficient Ratio
Belgium	0.11	3.60	0.33	0.30	1.12
France	0.02	3.80	0.29	0.30	0.97
Germany	0.01	4.80	0.27	0.30	0.91
Hungary	0.09	7.90	0.36	0.30	1.20
Ireland	0.19	9.20	0.38	0.30	1.28
Italy	0.02	7.80	0.32	0.30	1.09
Poland	0.03	7.80	0.33	0.30	1.10
Spain	0.05	5.50	0.33	0.30	1.11
United Kingdom	0.03	5.00	0.31	0.30	1.05

If one wanted to increase technological change in the European Union more agglomeration of economic activity and more entrepreneurial activity in Germany and France may increase the amount of knowledge spillovers and lead to growth. Increasing Research and Development expenditures, without increasing entrepreneurial activity, may not achieve the same result as if it was accompanied by entrepreneurial activity (Acs et al 2004, Michelacci, 2003). However, and this is perhaps the most important point, the effect of entrepreneurship on knowledge spillovers and therefore on technological change is weak in EU countries, and not strong, as suggested by some in the entrepreneurship literature. After taking into account the effect of the stock of knowledge and research and development expenditures, both agglomeration and entrepreneurship have a weak positive effect of technological change.

This result is rather surprising and there are several possible explanations for the week results of entrepreneurship. First, the TEA index might not be a good measure of technological opportunity. It is unlikely that a substantial high technological entrepreneurial sector will develop in the absence of broad national participation in entrepreneurship. Strong co-occurrence among these diverse measures indicated that the TEA index is a good measure of the overall level of entrepreneurial activity. Second, perhaps entrepreneurship is not as important in Europe as in the United States. This effect is stronger in the United States where the opportunity-based entrepreneurial activity is almost twice the European average. Third, we only have one year of data at the start of a recession. A longer time period may reveal different results. Finally, the inter relationship between agglomeration and entrepreneurship may indeed be important. However, we found no relationship between the two in this paper.

5. Conclusion

In this paper we have tested a modified endogenous growth model to ascertain the impact of agglomeration effects and entrepreneurial activity on technological change. Specifically we tested the impact of technological entrepreneurship and agglomeration effects on the spillover of new knowledge in economic growth. We find that the endogenous growth model developed by Romer (1990) does a good job of modeling economic growth. We also found support for the Jones (1995) assumption that the spillover effects from codified knowledge is less then one.

The effects of agglomeration effects on technological change are positive and statistically significant. The effect of entrepreneurship on technological change is positive but only marginally significant. When the interactive terms are taken into account the regression fit increases only slightly. Consequently we found significant, but weak effects of agglomeration and entrepreneurship on technological change for selected European countries. Given an elasticity of only 0.30 between research and technological change one would expect that this parameter could be raised. Recent work on the Knowledge Filter by Acs, et al (2004) suggests that reducing the filter between research input and economic output may increase economic growth.

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