Innovation and Economic Growth: Delineating the Impact of Large and Small Innovators in European Manufacturing

Jan-Bart Vervenne and Bart Van Looy

{jan-bart.vervenne, bart.vanlooy}@kuleuven.be
KU Leuven, Faculty of Business and Economics, Department of Managerial Economics, Strategy and Innovation, Naamsestraat 69, B-3000 Leuven (Belgium)

Abstract
In the course of the past decades, the link between innovation and economic growth has become a well-established one in the economic literature. In the current study an attempt has been provided to complement this line of research with an assessment of the wealth implications of the 'entrepreneurialisation' of innovation systems. Relying on a 9 year panel of post-millennial observations for 22 European countries and using stock based patent indicators, it was found that on top of the positive productivity impact of innovative activity growth, a premium effect can be observed when the stake of small firms in it increased at the same time. These findings can be interpreted as confirming Baumol's (2004) assignment of different roles to large and small firms in innovation systems: the former as provider of the technological breakthrough that the latter improves in a range of incremental steps. The entrepreneurialisation of manufacturing as a whole, measured by the stakes of small businesses in employment, yields a productivity discount: outside of innovative activities, economies of scale outweigh co-occurring diseconomies of scale. Distinct country groups in different stages of economic development form the main drivers of both entrepreneurialisation effects: a core of North-Western European countries that has attained the innovation-driven stage against a periphery of Southern and Eastern European countries around them that have not transcended the more preliminary efficiency-driven stage. Further rationales explaining the additional explanatory power of entrepreneurial innovation were found in the weakening of the link between innovation measured by patents and added value in large firms.

Conference Topic
Country-level studies; Patent analysis

Introduction

Substantial agreement exists among economists and policymakers that technological innovation is a key driver of sustainable economic growth. Technological innovation implies the implementation of inventions in the production of final goods or services and as such yields productivity gains for the innovating economy. Using knowledge capital to transform existing knowledge into such inventions, the amount of research and development (R&D) efforts is an important determinant of the pace of technological innovation.

Endogenous growth scholars have shown that technological innovation is an endogenous component of the process of long-run economic growth, both theoretically (Romer, 1986) as well as empirically (Nadiri, 1993). As opposed to their neoclassical counterparts (Solow, 1956), they postulate that technological innovation is an inherent component of the growth process: profit-maximising firms purposely allocate resources towards R&D in the presence of sufficient perspectives suggesting that they will be capable to appropriate the gains from it.

The analysis in this paper contributes to the mentioned line of research by complementing the measurement of overall technological innovation effects using patent statistics with an additional, patent-based indicator capturing the footprint of small, more entrepreneurial firms in the countries' stock of knowledge capital.[1] Further explanation for the rationale triggering

[1] Note that throughout this excerpt alternately we describe the firms of our interest as entrepreneurial or small. As Wennekers and Thurik (1999) argue, smallness and entrepreneurship can only be synonymous when management and ownership are not distinct. Subsidiaries of large business groups can qualify as small as well when shareholder information is not taken into account. This remark is of concern to us given the definition of small firms we will use in the empirical part (cf. below). However, given that small firms pertaining to larger

our interest to differentiate between innovation induced by small and large firms follows next. Subsequently methodology and results are reported, followed by some concluding notes. The focus on Europe in this study is justified among others by referring to the entrepreneurial innovation deficit Europe faces in comparison with the US (Veugelers, 2009).

Delineating the entrepreneurial contributions to innovation

The rationale to differentiate between incumbent and entrepreneurial innovation draws extensively from research on entrepreneurial innovation by Audretsch (2001), Baumol (2004) and Veugelers (2009). Whereas Schumpeter in 1942 predicted the gradual replacement of the entrepreneurial inventor - naturally associated with the small start-up - by routinized innovation organized by large industrials, Baumol (2004) emphasized the complementary relationship of both types of players within innovation systems. Their organizational design has induced them to specialize in different components of society's innovation process. Over the past decades revolutionary breakthrough inventions in the US have continued to come predominantly from small entrepreneurial enterprises whereas large industry have provided ever-increasing streams of incremental improvements to them multiplying capacity and speed and increasing reliability and user-friendliness. This is the result of the oligopolistic competition this relatively limited amount of very large firms, particularly in high-tech industries, engage in. It forces them to keep innovating in order to survive, but in a very risk-free and thus path-dependent way, avoiding the risks of the unknown that the revolutionary breakthrough entails. As such, inert incumbents leave plenty of room to explore for the enterprising entrepreneur. Unaffected by concerns relating to existing products and markets, the latter can pick up the ideas the former would deem too risky (Audretsch, 2001; Baumol, 2004). The other way around, incumbents are more suited to follow-up and improve those breakthrough innovations in more mature stages of the technology life-cycle (Baumol 2004).

Plugging the level of 'entrepreneurialisation' of innovation into a growth model

Methodology

The neo-classical growth model (Wong et al., 2005) we use to test a number of research questions distilled from the context described above is based on an augmented Cobb-Douglas production function:

$$Y = A^{O} K^{\propto} L^{\beta}$$

Where Y = output, A^{O}= total factor productivity, K = stock of physical capital and L = labor employed. Assuming constant returns to scale, $\alpha + \beta = 1$, both sides of the equation are then divided by labour. Taking natural logs the resulting model to estimate economic productivity per employee goes as follows:

$$\ln\left(\frac{Y}{L}\right) = lnA^{o} + \propto ln\left(\frac{K}{L}\right)$$

Following the approach by Wong et al. (2005), we assume that the stock of knowledge capital is the main determinant of total factor productivity, A^{O}. The stock of knowledge capital is captured using technological innovation statistics, among which patent based-indicators comprise one of the best proxies. More specifically, the level of innovation (*INNO)* is measured using stocks of patent applications depreciating at a rate of 20% per year as the

conglomerates in the countries of our sample never comprise a majority, on average our population of small firms can be described as 'more entrepreneurial'.

effects of investment in innovation transcend the short run.[2] The technological innovation variable was normalized by employment to capture its intensity and limit the effects of country size as much as possible. As suggested in the previous section, as factor of total productivity the general intensity of technological innovation is complemented by a patent-based indicator, measuring the degree of small firm engagement in innovative activity, and an equivalent employment-based indicator to control for overall small firm activity. The latter to make sure increased innovative activity of small firms is not simply capturing the potential productivity effects of an increase in entrepreneurial activity in general.

Determining the degree to which national innovation systems have ran on entrepreneurial initiative was based on the assignment of patents to small and large firms using the methodology presented in Eurostat (2014).[3] Due to shortcomings in the matching methodology and data gaps in the financial database - among others the result of country-specific disclosure exemptions rewarded to certain company types - only for approximately 62% of the corporate applicants in Europe firm size could be determined. We assume however that these country-level constraints equally hold for all years of the sample and as such are coped with by estimating coefficients using country fixed effects (cf. infra).

The effects of entrepreneurial and incumbent engagement in innovation could not just be measured by plugging raw stocks of their respective patent applications into the equation: R&D clustering dynamics within countries result in a high correlation – more than 0.97 even when removing country effects – with the annual innovative activity deployed by the national innovation system as a whole, that is already captured in the core variable measuring technological innovation. Given our main interest towards the benefits of entrepreneurial innovation and to avoid multicollinearity, the degree of ‘entrepreneurialisation’ of corporate technological innovation (*ENTR_INNO*) was measured by computing the share of small firms in the stock of patents assigned to firms with identified size.

The within variance of this share value captures to what extent small firms have shown relative over- or underactivity in R&D in comparison with their large counterparts. Given the large level of correlation among the small firm, large firm and overall patent stocks it is safe to assume that entrepreneurial and incumbent innovation do not have an opposite effect on economic productivity which would hamper a straightforward interpretation of *ENTR_INNO*. At most one of them can have a relatively larger impact on productivity. In line with the rationale elaborated above we expect that to be the small innovators. The result of that should

[2] All patent statistics were extracted from EPO’s Worldwide Patent Statistical Database ‘PATSTAT’ (Autumn version 2014). In general we relied on EPO patent applications, including granted and non-granted patents, with the idea that counting both yields a relatively more input-oriented measure capturing the level of R&D spending than if one would stick to grants only (Ernst, 2003). Depreciation of the patent stock at a rate of 20% per year is based on the perpetual inventory method described in Ulku (2004). The patent stock variable incorporates annual EPO patent counts from 1970 onwards. The restriction of our attention to EPO patents can be easily justified given the geographical reach of our dataset and their costliness, which is a direct result of their supra-national character. Being that expensive, especially for more financially constrained SMEs, counts of them at the macro-level bear the potential to be good signals of R&D input & output levels per country over time.

[3] The lack of dynamic shareholder data in BvD’s Amadeus (a database gathering annual account information) withheld us from determining firm size at the business group level. In contrast with the matching exercise presented in Eurostat (2014), firm size was determined dynamically by linking patents to financial information from the financial years that corresponded with the patent application filing year. In addition financial account data from Amadeus 2012 was enriched with equivalent information from earlier versions (2004 and 2007) to dispose of financial information in the earliest years of the matched sample (1999-2011) and to account for the BvD rule to discard companies not filing accounts for 5 years in a row. Firm size – or rather entity size – classification for patenting companies from 1999 onwards was based on the European Commission SME definition (2005): enterprises that employ fewer than 250 employees and which have an annual turnover not exceeding 50 million euro, and/or an annual balance sheet total not exceeding 43 million euro.

be *ENTR_INNO* exerting a positive effect on productivity, which would imply the existence of a productivity premium to an increased entrepreneurial stake in corporate innovation.
Given that the large majority of patents in Europe can be assigned to the manufacturing industry (Fraunhofer, 2003), downloads of observations for the non-patent based variables of country *c* in year *t* were restricted to that sector. Indicators for value added at factor cost (*VAFC*), the number of persons employees (*NPE*), gross investment in tangible goods (*GITG*) and the share of small firms in corporate employment (*ENTR_EMP*) were extracted from the Eurostat website.[4] [5] Furthermore, a quadratic year trend is included to capture time effects.[6] Conform previous research all R&D related indicators are lagged since it is assumed that the effects of R&D on economic performance take a couple of years to surface. In line with Ulku (2004) and given the limited time-series at our disposal we opted for a 2-year time lag. Following an equivalent rationale, the physical investment and share of entrepreneurial employment variables were also lagged by 1 year.
The resulting equation to be estimated using panel data techniques is:

$$lnVAFC/NPE_{ct} = \propto + \beta_1 lnGITG/NPE_{c,t-1} + \beta_3 INNO/NPE_{c,t-2} + \beta_4 ENTR\_INNO_{c,t-2} + \beta_5 ENTR\_EMP_{c,t-1} + year + year^2 + u_c + \varepsilon_{ct}$$

Results

Coefficients are estimated using fixed effects OLS.[7] Table 1 reports the estimation results, including robust standard errors, for the overall set of European countries (panel 1: ALL) and split sets of countries that lead (panel 2: LEADERS) or lag behind (panel 3: LAGGARDS) in terms of innovation according to the European Commission's (EC) Innovation Union Scoreboard (2015). The left hand of each panel contains estimates for the basic model as expressed in the equation above. The right hand side in addition reports an additional interaction effect between the technological innovation intensity and its degree of 'entrepreneurialisation'.

Conclusion and directions for future research

Apart from confirming previous findings regarding the positive impact of technological innovation on economic output, overall results (ALL) reveal that there is an additional productivity premium to a larger share of entrepreneurial engagement in the development of new, patented technology. The entrepreneurialisation of employment on the other hand, a broader measure of corporate activity, appears to be negatively associated with productivity.

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[4] The resulting set of 22 countries consists of: Austria, Belgium, Germany, Denmark, Finland, France, United Kingdom, the Netherlands, Norway, Slovenia, Sweden (LEADERS), Czech Republic, Cyprus, Estonia, Greece, Hungary, Italy, Latvia, Poland, Portugal, Slovakia and Spain (LAGGARDS). Other European countries were discarded for multiple reasons: a lack of employment, investment or gross added value statistics available to the public or a too low rate of patenting companies matched to companies in the financial database, as such, hampering a representative image of the distribution of patents between incumbents and small businesses. Unusual annual productivity growth induced by preferential tax regimes for foreign firms, inciting those to shift profits to local subsidiaries, resulted in elimination of Ireland and Luxemburg from the sample as well.
[5] All currency-based series – expressed in Euro – were deflated using per country GDP price deflators (World Bank WDI website). Due to the lack of availability of stock variables capturing the total amount of outstanding fixed capital, in line with Ulku (2004) we used the flow variant.
[6] Preferably time dummies are included but using a functional form, in this case a quadratic trend allowing for one up and one down trend, can be an alternative in order to preserve degrees of freedom. Results turned out to be largely consistent for trend- and dummy-based models.
[7] Correlations among demeaned variables suggest that multicollinearity is not an issue for within-transformed variables.

Table 1. OLS fixed effects regression results.

	ALL		LEADERS		LAGGARDS	
ln_GITG/NPE (1y lagged)	0.676	0.529	0.686	-0.014	0.578**	0.825***
	(1.23)	(1.11)	(1.0)	(0.03)	(2.51)	(4.81)
INNO/NPE (2y lagged)	0.872**	-1.936	-0.736	-3.615*	-1.378	7.178
	(2.11)	(1.60)	(0.63)	(2.17)	(1.03)	(1.12)
ENTR_INNO (2y lagged)	0.003	-0.011	0.018	-0.114**	0	0.007
	(0.56)	(1.29)	(0.53)	(2.30)	(0.06)	(1.31)
INNO/NPE * ENTR_INNO (both 2y lagged)		7.873**		13.545***		-16.253
		(2.66)		(3.40)		(1.29)
ENTR_EMP (1y lagged)	-0.044**	-0.040**	-0.046	-0.053	-0.039**	-0.037**
	(2.67)	(2.38)	(1.06)	(0.90)	(2.82)	(2.56)
year	0.800**	0.699*	0.925	0.692	0.572**	0.590**
	(2.17)	(2.01)	(1.32)	(1.07)	(2.58)	(2.75)
year²	0.000**	0.000*	0.000	0.000	0.000**	0.000**
	(2.17)	(2.01)	(1.32)	(1.06)	(2.58)	(2.75)
_cons	-803.722**	-701.719*	-930.145	-695.108	-574.378**	-593.032**
	(2.18)	(2.01)	(1.33)	(1.07)	(2.59)	(2.76)
# observations	177	177	92	92	85	85
# groups	22	22	11	11	11	11
F statistic	38.62	51.13	39.55	44.54	29.68	149.8
R-squared Within	0.49	0.53	0.48	0.54	0.77	0.79
R-Squared Between	0.54	0.58	0.19	0.24	0.3	0.23

* *p*<0.1; ** *p*<0.05; *** *p*<0.01

The dynamics behind these observed effects could be explained among others by referring to a mix of economies and diseconomies of scale (Brock & Evans, 1989). The observation of an entrepreneurial innovation premium could be attributed to the higher likelihood that patents introduced by small businesses will be high impact ones, making the average small firm patent more technically and thus more economically important. This finding complies with Baumol's (2004) assignment of different roles to small and large firms in innovation systems with the former being relatively better at the introduction of radical new technologies and the latter in perfecting those by incremental improvements. The observed discount observed on the entrepreneurialisation of employment suggests that in the non-innovation-related aspects of business operations the economies of scale outweigh the diseconomies of scale. This observation counters earlier findings underlining the increasing importance of non-technologically oriented scale diseconomies that result from growing markets valuing specialized products, increasing advantages to flexibility in a globalized world, the rising availability of educated labour to recruit from and decreasing standard fixed costs of running a business (Brock & Evans, 1989).

Separate results for countries tagged by the EC as innovation leaders and laggards further reveal some of the potential deeper dynamics behind this. Not surprisingly, the innovation leaders turn out to be the driving force behind the productivity premiums to technological innovation in general and entrepreneurial innovation. The former and latter can be seen as highly intertwined: established knowledge-based economies possess the critical mass that is necessary to produce knowledge that matters. Knowledge stock growth in turn increases the potential for spill-overs of various ideas to entrepreneurs. On top of that, local rivalry between high-tech entrepreneurial ventures capturing the same localized knowledge flows increases their respective efficiency (Furman et al., 2002). The laggard countries appear to be the driving force behind the productivity discounts associated with small firm employment share growth. The distinct geographic origins of the premium effect on entrepreneurial innovation and discount effect on entrepreneurial employment confirm the heterogeneous nature of the European economic landscape. Relying on Porter et al.'s (2002) framework of economic development to explain differences between split dataset results one could claim that it consists of less developed countries in a 'preliminary' efficiency-driven stage and more advanced countries in the 'final' innovation-driven stage (Porter et al., 2002; Acs et al., 2008).

In a complementary attempt to explain the additional explanatory power of entrepreneurial innovation in general we refer to the increasing disjunction between patents as measure of innovation and productivity in large firms: the availability of in-house IP departments increase their propensity to patent low-value inventions and tax optimization strategies applied by multinationals blur the value of license fees as proxy for added value.

Future research is necessary to further disentangle the mechanics behind the observed effects. Measurement of knowledge spill-overs could help to provide insights about their nature, origins and the direction in which they are heading. Adding proxies capturing the distinct drivers of scale diseconomies is another potential direction for future research. Further inquiry is also needed to list the policy implications of our findings.

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