

Pellegrino, Gabriele; Piva, Mariacristina; Vivarelli, Marco

Working Paper

How do young innovative companies innovate?

Jena Economic Research Papers, No. 2009,055

Provided in Cooperation with:

Max Planck Institute of Economics

Suggested Citation: Pellegrino, Gabriele; Piva, Mariacristina; Vivarelli, Marco (2009) : How do young innovative companies innovate?, Jena Economic Research Papers, No. 2009,055, Friedrich Schiller University Jena and Max Planck Institute of Economics, Jena

This Version is available at:

<https://hdl.handle.net/10419/32564>

Standard-Nutzungsbedingungen:

Die Dokumente auf EconStor dürfen zu eigenen wissenschaftlichen Zwecken und zum Privatgebrauch gespeichert und kopiert werden.

Sie dürfen die Dokumente nicht für öffentliche oder kommerzielle Zwecke vervielfältigen, öffentlich ausstellen, öffentlich zugänglich machen, vertreiben oder anderweitig nutzen.

Sofern die Verfasser die Dokumente unter Open-Content-Lizenzen (insbesondere CC-Lizenzen) zur Verfügung gestellt haben sollten, gelten abweichend von diesen Nutzungsbedingungen die in der dort genannten Lizenz gewährten Nutzungsrechte.

Terms of use:

Documents in EconStor may be saved and copied for your personal and scholarly purposes.

You are not to copy documents for public or commercial purposes, to exhibit the documents publicly, to make them publicly available on the internet, or to distribute or otherwise use the documents in public.

If the documents have been made available under an Open Content Licence (especially Creative Commons Licences), you may exercise further usage rights as specified in the indicated licence.



JENA ECONOMIC RESEARCH PAPERS



2009 – 055

How do young innovative companies innovate?

by

**Gabriele Pellegrino
Mariacristina Piva
Marco Vivarelli**

www.jenecon.de

ISSN 1864-7057

The JENA ECONOMIC RESEARCH PAPERS is a joint publication of the Friedrich Schiller University and the Max Planck Institute of Economics, Jena, Germany. For editorial correspondence please contact markus.pasche@uni-jena.de.

Impressum:

Friedrich Schiller University Jena
Carl-Zeiss-Str. 3
D-07743 Jena
www.uni-jena.de

Max Planck Institute of Economics
Kahlaische Str. 10
D-07745 Jena
www.econ.mpg.de

© by the author.

HOW DO YOUNG INNOVATIVE COMPANIES INNOVATE?

July 2009

Gabriele Pellegrino

Università Cattolica del Sacro Cuore, Piacenza and Milano

Mariacristina Piva

Università Cattolica del Sacro Cuore, Piacenza and Milano

Marco Vivarelli

Università Cattolica del Sacro Cuore, Piacenza and Milano;
IZA, Bonn;
Max Planck Institute of Economics, Jena

Abstract

This paper discusses the determinants of product innovation in young innovative companies (YICs) by looking at in-house and external R&D and at the acquisition of external technology in embodied and disembodied components. These input-output relationships are tested on a sample of innovative Italian firms. A sample-selection approach is applied.

Results show that in-house R&D is linked to the propensity to introduce product innovation both in mature firms and YICs; however, innovation intensity in the YICs is mainly dependent on embodied technical change from external sources, while -in contrast with the incumbent firms- in-house R&D does not play a significant role.

JEL-classification: O31

Keywords: R&D, product innovation, embodied technical change, CIS 3, sample selection.

Contact: Prof. Marco Vivarelli, Facoltà di Economia, Università Cattolica, Via Emilia Parmense 84, I 29100 Piacenza, Email: marco.vivarelli@unicatt.it

1. Introduction

Increasing interest is being shown by both the scientific community and policy makers in the role of young innovative companies (YICs) in the new technology implementation process, which contributes to the renewal of the industrial structure and ultimately to aggregate economic growth¹. For instance, one of the possible explanations of the transatlantic productivity gap could be found in the revealed capacity of the US economy to generate an increasing flow of young innovative firms which manage to survive and introduce new products, taking their place at the core of emerging sectors. On the contrary, young European firms reveal lower innovative capacity and most of them are doomed to early failure, the process resulting in churning rather than innovative industrial dynamics (see Bartelsman *et al.*, 2004; Santarelli and Vivarelli, 2007).

There are several different sources of innovation at the firm level; together with in-house and external R&D activities, technological acquisition (TA) in its embodied (machinery and equipment) and disembodied components also has to be taken into account. This input-output framework can be seen as an extension of the "Knowledge Production Function" (KPF, initially put forward by Griliches, 1979), a feasible tool for describing the transformation process running from innovative inputs to innovative outputs.

While most previous microeconomic research has focused on the R&D-Innovation-Productivity chain (see next section), few studies have explicitly discussed the role of TA and the possible differences in the KPF across firms of different ages. By using microdata from the European Community Innovation Survey 3 (CIS 3) for the

¹ For instance, several EU Member States have introduced new measures to support the creation and growth of YICs, especially by improving their access to funding (see BEPA, 2008; Schneider and Veugelers, 2008).

Italian manufacturing sector, the main novelty of this paper lies in the authors' investigation of whether R&D and TA lead to significant differences in determining innovative output in firms of different ages. In particular, it will be tested whether the KPF of YICs exhibits some peculiarities in comparison with what emerges in the case of mature incumbent firms.

The remainder of the paper is organised as follows: a discussion of the theoretical framework on which this work is based (Section 2) is followed by a description of the data and indicators used in the empirical analysis and by discussion of the adopted econometric methodology (Section 3). Subsequently, the empirical outcomes derived from the descriptive analysis and the econometric estimates (Section 4) are discussed. Section 5 concludes the paper by briefly summarising the main findings obtained.

2. The literature

Previous economic literature has taken R&D and patents as a starting point for the analysis of innovative activities across economies, industries and firms. In particular, the relationship between innovative inputs and outputs explicitly appears as one of the components of those analyses whose main target is to measure the returns on innovation. In this stream of literature, the first contribution to discuss the innovative input-output relationship was by Griliches (1979 and 1990), through a three-equation model in which one of the equations is what he called the Knowledge Production Function (KPF), a function intended to represent the transformation process leading from innovative inputs (R&D) to innovative outputs (patents)². Similarly, the KFP is also included in the models provided by Crèpon *et al.* (1998) and Lööf and Heshmati (2001).

² The other two equations in Griliches' simultaneous model represent the production function (augmented by the innovation term) and the determinants of R&D investment. See also Hall (1996), Hall (2000), Mairesse and Mohnen (2002), Harhoff *et al.* (2003) and Hall *et al.* (2005).

The theoretical framework so far described has provided the background for understanding the link between innovative inputs and outputs and for the empirical assessment of this relationship. However, for the particular purpose of this paper, most of the previous empirical studies suffer from two main limitations. Firstly, the relationship between innovation inputs and innovation outputs is not their main focus but rather a secondary equation, ancillary to the authors' main purpose of investigating firms' performance in terms of productivity and/or profitability. Secondly, and more importantly, the KPF is simplified as a link between R&D and patents. Historically driven by relative availability with respect to other measures of innovation, the relationship between a firm's R&D investment and patenting activity leaves room today for a more comprehensive approach to the determinants of its innovativeness. In particular, nowadays innovation surveys provide more precise and comprehensive measures of both innovative inputs and outputs³.

Consistently, different innovation outputs can be seen as the outcomes of several innovation inputs and not only as the consequence of formal R&D investments⁴. For instance, it is important to consider the role of technological acquisition (TA), both

³ Patents turn out to be a very rough proxy of innovation for several reasons: 1) not all innovations are patented (firms generally prefer other ways of protecting their innovation, see Levin *et al.*, 1987); 2) patents are very rare among small innovative firms and YICs; 3) patents differ greatly in their importance; 4) firms in different sectors show very different propensities to patent (see Archibugi and Pianta, 1992; Patel and Pavitt, 1995).

⁴ This broader perspective is also endorsed in methodological advice as to the collection of data regarding innovation; in particular, this is well represented by the shift from the R&D-focused Frascati Manual ("Guidelines for the collection of R&D data", first published in 1963) to the Oslo Manual in the 1990s (OECD, 1997).

through ‘embodied technical change’⁵ acquired by means of investment in new machinery and equipment, and through the purchasing of external technology incorporated in licences, consultancies, and know-how (Freeman, 1982; Freeman *et al.*, 1982; Freeman and Soete, 1987).

This paper represents an attempt to open up this broader perspective. Once it has been recognized that innovative inputs are not confined to formal R&D and that innovative outputs can be measured by other (more satisfactory) indicators than patents⁶, we pave the way for a deeper analysis of firms’ peculiarities in the KPF. In this framework, firms adapt their innovative strategy to their own particular economic environment by choosing the most effective combination of innovative inputs and outputs. In doing so, they distribute economic resources between formal in-house and external R&D, technological change embodied in machinery and equipment and the purchasing of external know-how and licenses.

In particular, we wonder whether YICs differ from mature incumbents in their input-output innovative relationships. Are YICs more R&D-based and conducive to a science-based reorientation of the current industrial structure?⁷ Or on the contrary, are

⁵ The embodied nature of technological progress and the effects related to its spread in the economy were originally discussed by Salter (1960); in particular, vintage capital models describe an endogenous process of innovation in which the replacement of old equipment is the main way through which firms update their own technologies (see also Jorgenson, 1966; Hulten, 1992; Greenwood *et al.* 1997).

⁶ See Nelson and Winter (1982) and Dosi (1988) for an extended and more articulated view of the innovative process across firms.

⁷ This seems to be the view implicitly accepted in the literature on the so-called “New Technology Based Firms” (NTBFs, see Storey and Tether, 1998; Colombo and Grilli, 2005), where only YICs in the high-tech sectors are analyzed; in contrast, in this paper YICs across all sectors are studied. While in this study we compare YICs with mature innovative incumbents, a related stream of literature investigates the role of innovation in facilitating the entry and post-entry performance of newborn firms (see Audretsch and

YICs weaker than innovative incumbents and so less R&D-based and basically dependent on external knowledge provided by larger mature firms and research institutions?

The hypothesis of small and newly established firms being more science-based and technologically advanced is consistent with the entrepreneurial process of ‘creative destruction’ (Schumpeter, 1934; the so-called Schumpeter Mark I), while the process of ‘creative accumulation’ calls for large and established firms to take a leading role in the innovative process (Schumpeter, 1942; Schumpeter Mark II). Adopting evolutionary terminology, the former context can be seen as an ‘entrepreneurial regime’, where new firms and the industrial dynamics are the basic factors of change, while the latter can be considered a ‘routinized regime’, where larger and older incumbents are the engines of change and lead the innovative process (see Winter, 1984; Malerba and Orsenigo, 1996; Breschi *et al.*, 2000).

Indeed, when focusing on all the industrial sectors and not only the emerging or the high-tech ones, several arguments sustain the view that larger mature firms might turn out to be more R&D based than their younger counterparts. Firstly, mature larger incumbents are not affected by liquidity constraints since they have both easier access to external finance and more internal funds to support R&D activities which are both costly and uncertain. Secondly, larger incumbent firms possess a higher degree of market power and so enjoy a higher degree of “appropriability” (Gilbert and Newbery, 1982). Empirically, Cohen and Klepper (1996) provide stylised facts supporting the view that the likelihood of a firm carrying out R&D increases with size, while Mairesse and Mohnen (2002) highlight the scale economies and the differences in the organisation of work that make larger established incumbents more inclined to carry out R&D activities.

Vivarelli, 1996; Arrighetti and Vivarelli, 1999; Cefis and Marsili, 2006). Finally, in this paper only innovative firms are studied, while another related field of studies investigates the different propensity to innovate according to a firm’s age (see Hansen, 1992; Huergo and Jaumandreu, 2004).

Thirdly, learning economies (see Arrow, 1962; Malerba, 1992) are often crucial in innovative dynamics and older (experienced) firms are obviously at an advantage from this perspective.

However, not all innovative firms are large established corporations. Indeed, economic literature supports the hypothesis that small and young firms face a different technological and economic environment from large mature firms with respect to innovative activities (see Acs and Audretsch, 1988 and 1990; Acs *et al.*, 1994). In particular, as discussed above, R&D does not represent the sole input through which firms can produce some innovative outcomes. While the financial and competitive reasons discussed above can hamper an R&D-based innovative strategy for YICs, it seems much easier for them to rely on the market and choose "to buy" instead of "to make" technology (Acs and Audretsch, 1990). One of the hypotheses to be tested in this paper is therefore whether an innovation outcome in YICs relies more on external sources of knowledge than on formal in-house R&D. This hypothesis appears even more plausible in a middle-technology economy, such as that of Italy, where middle-tech and traditional sectors represent the core of the industrial structure (for recent evidence on the crucial role of embodied technical change and other external sources of knowledge in spurring innovation in the medium and low-tech sectors, see Santamaría *et al.*, 2009).

In the specific Italian 'national innovation system' (see Freeman, 1987, Lundvall, 1992 and Nelson, 1993, for an introduction to the concept; Malerba, 1993, for an application to the Italian case), NTBFs may be an exception, while for YICs the main way to acquire knowledge might be through embodied technical change and technological acquisition (for previous evidence on the role of embodied technological change in fostering innovation in Italian manufacturing firms, see Santarelli and Sterlacchini, 1990, and Conte and Vivarelli, 2005).

3. Dataset, indicators and methodology

The empirical analysis was carried out using microdata drawn from the third Italian CIS, conducted over a three-year period (1998-2000) by the Italian National Institute of Statistics (ISTAT). This survey is representative at both the sector and the firm size level of the entire population of Italian firms with more than 10 employees. The CIS 3 dataset adopts a weighting procedure that relates the sample of firms interviewed to the entire population⁸ (ISTAT, 2004).

The dataset comprises a set of general information (main industry of affiliation, group belonging, turnover, employment, exports) and a (much larger) set of innovation variables measuring the firms' innovativeness, economic and non-economic measures of the effects of innovation, subjective evaluations of factors hampering or fostering innovation, participation in cooperative innovation activities and access to public funding. The response rate was 53%, determining a full sample size of 15,512 firms, 9,034 of which (58.24%) in the manufacturing sector, our focus of attention. The manufacturing sample was then cleaned of outliers and firms involved in mergers or

⁸ Firm selection was carried out through a "one step stratified sample design". The sample in each stratum was selected with equal probability and without reimmission. The stratification of the sample was based on the following three variables: firm size, sector, regional location. Technically, in the generic stratum h , the random selection of $n_{\{h\}}$ sample observations among the $N_{\{h\}}$ belonging to the entire population was realized through the following procedure:

- a random number in the 0-1 interval was attributed to each $N_{\{h\}}$ population unit;
- $N_{\{h\}}$ population units were sorted by increasing values of the random number;
- units in the first $n_{\{h\}}$ positions in the order previously mentioned were selected.

Estimates obtained from the selected sample are very close to the actual values in the national population. The weighting procedure follows Eurostat and Oslo Manual (OECD, 1997) recommendations: weights indicate the inverse of the probability that the observation is sampled. Therefore, sampling weights ensure that each group of firms is properly represented and correct for sample selection. Moreover, sampling weights help in reducing heteroscedasticity commonly arising when the analysis focuses on survey data.

acquisitions during the previous three years, which would have biased our results⁹. We thus ended up with 7,965 innovating and not-innovating firms.

The sub-sample of innovators was then selected following the standard practice of identifying innovators as those firms declaring that in the previous three years they had introduced product or process innovations, or had started innovative projects (then dropped or still-to-complete at December 31st, 2000). The same definition was implemented by ISTAT as a filter to save non-innovators having to plough through all the questions not relevant to them (with the risk of non-innovating firms not responding to the rest of the questionnaire). Thus, firms identified as non-innovators were allowed to skip a large number of ‘innovation questions’, leaving us with very little information about their propensity to innovate or to invest in innovative inputs. This means that the CIS database provides information relevant to this study only for innovative firms; therefore only these firms were considered in the following analysis¹⁰, ending up with 3,045 firms. This sample was further reduced to 2,713 firms by keeping only firms investing in at least one of the four innovative inputs we focus on. Finally, YICs were identified as young firms with less than eight years of activity (293 out of 2,713)¹¹.

⁹ In fact, mergers and acquisitions may break the link between innovative inputs and outputs (a link that must be studied within the context of a single firm).

¹⁰ Given that our aim is that of analyzing the nature of the relationships within the innovative process (and not, for example, the effect of different inputs in determining the probability of innovating), this data limitation does not raise a problem of selection bias. Since we are interested in the internal mechanisms of the innovative process, we have to focus on a randomly selected sample of innovative firms (that is, randomness must hold *within* the innovative sub-sample, not in comparison with the non-innovative one where such mechanisms are obviously absent). For a study based on a comparison *between* innovative and non-innovative Italian firms, see Parisi *et al.* 2006.

¹¹ As far as the age of the firms in the ‘young firms’ sub-sample is concerned, the threshold of 8 years was chosen to take into account the trade-off between a lower age and the representativeness of the sub-sample

3.1. Innovative outputs

Innovative outputs can be distinguished with respect to their position in the innovation process. For instance, while patents are better defined as the outcome of the inventive process, product innovation properly represents the result of the market-oriented innovative process. However, even though product innovation is driven by demand considerations, it represents a pre-market result. In contrast, the share of sales deriving from innovative products (Mairesse and Mohnen, 2002) represents an *ex-post* result in which the market has positively welcomed the new products introduced by the firm (Barlet *et al.*, 2000).

Taking these considerations and the interpretative background discussed in Section 2 into account, this paper uses two available output indicators for the empirical analysis: namely, the introduction of product innovation (PROD), and the share of turnover (sales) derived from innovative products (TURNIN)¹². It is worth noting that this sales-weighted measure of innovation is the only continuous output indicator provided by the CIS and it indicates the intensity of innovation (Löf and Heshmati, 2002; Mairesse and Mohnen, 2002).

3.2. Innovative inputs

of YICs (here almost 10% of the entire sample). However, estimates in Section 3.4 were replicated using a larger sample of young firms no more than 10 years old. The results, available from the authors upon request, do not change substantially.

¹² It is worth emphasizing the link adopted in the questionnaire design; this link goes from product innovation to the sales ratio indicator since only firms that have introduced product innovation can record a positive percentage of their sales as being derived from product innovation. This raises an issue of sample selection that will be discussed in the next methodological Section 3.4.

Bearing in mind the theoretical discussion presented in Section 2, four innovative inputs are used in this paper: in-house and external expenditures in formal Research and Development (intra muros R&D = IR); Research and Development outsourced to other firms or research institutes (extra muros R&D = ER); expenditures in embodied technological change (innovative investment in equipment and machinery = MAC); and expenditures in technology acquisition (disembodied technology such as know-how, projects and consultancies, licenses and software = TA).

3.3. Control variables

CIS 3 provides further information on firms beyond their innovative activity. Econometric estimates in this paper adopt some of these indicators as further controls and explanatory variables. Attention is paid to the following control variables:

1. Firm's export propensity (EXPint): global competition can spur innovation and capabilities, while technologically inactive firms are doomed to exclusion from the international arena (e.g. Archibugi and Iammarino, 1999; Narula and Zanfei, 2003).
2. Firm's belonging to an industrial group (IG): Mairesse and Mohnen (2002) underline the expected innovative benefits due to easier access to (internal) finance and to the effect of intra-group knowledge links for firms that are members of industrial groups.

3. Firm's access to policy support (SUPPORT): a government subsidy or a fiscal incentive should increase a firm's innovative performance, although the empirical evidence on this is quite controversial¹³.
4. Firms participating in a cooperation agreement (COOP): as regards the important role of cooperation agreements in affecting the innovative output of firms see Cassiman and Veugelers (2002), Piga and Vivarelli (2003 and 2004), Fritsch and Franke (2004).
5. Appropriability: the availability and use of different instruments for achieving a larger degree of appropriability of the innovation rent, such as patents (PATENT), trademarks, secrecy, etc. (PROT) (see Levin *et al.*, 1987) should positively affect the innovative performance.
6. While the recognized obstacles to innovation (such as financial constraints or organizational hindrances) (HURDLE) should obviously damage innovative performance, the occurrence of other forms of innovation (such as organizational change, see Bresnahan *et al* 2002; Hitt and Brynjolfsson, 2002; Piva *et al*, 2005)

¹³ In fact, while public funding should stimulate (in absolute terms) both the input and the output side of innovation, a crowding out effect seems to operate, displacing (totally or partly) privately funded innovation activities. Using a dataset of firms which benefited from the Small Business Innovation Research Program, Wallsten (2000) even comes to the conclusion that R&D grants completely crowd out firm-financed R&D spending, dollar for dollar. The view of Gonzáles *et al.* (2005) is much more optimistic: they found no evidence of crowding out. Using an unbalanced panel of more than 2000 Spanish manufacturing firms, the authors show that government intervention stimulates R&D activities. Midway between such extreme results, the majority of existing empirical literature on the subject shows that public support fosters innovation, crowding out effects operating only partially (see Busom, 2000).

(OTHERIN) should be complementary to the four innovative inputs described in the previous section.

Finally Pavitt's sectoral dummies (Pavitt, 1984) were added to the econometric specification in order to control for the different sectoral technological opportunity and appropriability conditions.

Table 1 briefly describes the variables used in the empirical analysis, while Table 2 reports the corresponding descriptive statistics¹⁴.

< INSERT TABLES 1 AND 2 >

3.4. *Econometric issues*

Equation (1) describes the general specification adopted for the aggregate empirical test of the innovative input-output relationship:

$$\text{TURNIN}_i = C + \beta_1 \text{IRint}_i + \beta_2 \text{ERint}_i + \beta_3 \text{MACint}_i + \beta_4 \text{TAint}_i + \sum \beta_j X_{ji} + \sum \gamma_k \text{PAVITT}_{ki} + \varepsilon \quad (1)$$

where C is the constant, i is the firm-index, TURNIN represents the innovative output in terms of the percentage of sales due to innovative products, IR, ER, MAC and TA indicate the innovative inputs we are interested in, X is the vector of the (max j=8) control variables and PAVITT are the sectoral dummies (Science-based, Scale intensive and Specialised suppliers, with the Suppliers-dominated as the default category; k=3).

¹⁴ In Appendix A1 the sectoral compositions of the two subsamples of mature firms and YICs are reported: as can be seen, with regard to most sectors no significant differences emerge; however, to be on the safe side, all the regressions were controlled for Pavitt's sectoral dummies. In Appendix A2, the correlation matrix for the entire sample is reported; as can be seen, all the correlation coefficients are less than 0.371, showing that data are not affected by serious collinearity problems. Corresponding tables for the subsamples of only the innovative firms are available upon request. Finally, Appendix A3 reports the CIS questions on the basis of which the variables were constructed.

Consistently with the dependent variable, the four innovative inputs were normalized by sales; this makes the inputs homogeneous to the output and also controls for the scale effect due to the different sizes of the investigated firms.

As a consequence of the questionnaire's design, the adopted sales-weighted measure of a firm's innovativeness (TURNIN) assumes a positive value only for firms that have introduced product innovation (PROD). This raises an obvious problem of sample selection that has to be dealt with. In particular equation (1) was tested jointly with a selection probit equation (2) of the type:

$$P(\text{PROD}_i=1) = C + \beta_1 \text{IRint}_i + \beta_2 \text{ERint}_i + \beta_3 \text{MACint}_i + \beta_4 \text{TAint}_i + \sum \beta_j Z_{ji} + \sum \gamma_k \text{PAVITT}_{ki} + \varepsilon_i \quad (2)$$

where Z is an extended vector of controls in equation (1), with $X \in Z^{15}$.

Both the high values of the correlation coefficients (ρ) between the selection and the main equation and the statistical significances of the Mills ratios in the three models (all firms, mature firms, YICs) (see Table 3) confirm the validity of the choice of a Heckman-Type (see Heckman, 1979) specification.

< INSERT TABLE 3 >

4. Empirical results

Table 3 reports the econometric results of the sample selection model applied to the entire sample and separately to the two sub-samples of the mature incumbents and the YICs. As can be seen, in-house R&D is important in increasing the likelihood of product innovation for the entire sample, although this link is less significant for the YICs. More importantly and in contrast with the mature firms, innovation intensity (TURNIN) is not related to internal R&D (IR) as far as the YICs are concerned. Far from being NTBFs, Italian YICs do not turn out to be R&D based, but rather dependent on external sources of knowledge.

¹⁵ X and Z were differentiated, taking into account the statistical significance of the different controls in the two equations, the occurrence of convergence in all the three models and the need for a homogeneous comparison between them. However, results are robust to different specifications of the sample selection model (available upon request).

The above result becomes obvious if we turn our attention to the other three innovative inputs. Neither external research (ER) nor technological acquisition (TA) seem to play a significant role in spurring product innovation in Italian manufacturing firms. However, in contrast with what happens for well-established incumbents, their impact is positive, although not significant, with regard to the YICs. Although statistically very weak, this outcome may suggest a possible role of ER and TA in facilitating innovation in the young firms.

Much more statistically robust is the outcome concerning the “embodied technical change” variable MAC. While rendering product innovation less likely¹⁶, MAC is positively and significantly (1%) linked to the innovation intensity in all the three models.

However, the coefficient is more than double the size in the case of the YICs. This means that Italian YICs are particularly dependent on the embodied technical change incorporated in machinery and equipment purchased from external sources. Together with what was found in relation to the non-significant impact of IR, this means that the investigated YICs lack endogenous technological capabilities, while they are massively dependent on technologies coming from other firms through input-output relationships. On the whole, these results highlight a potential weakness of Italian YICs, which seem to lack an endogenous capacity to sustain their own innovative activities.

Briefly looking at the control variables, not surprisingly (see Section 3.3) we notice that exporting and science-based YICs are more likely to perform better in terms of innovative intensity. Instead, and in contrast with the mature firms, YICs do not seem to be established enough to be responsive to variables such as HURDLE, OTHERIN and PROT. This can be seen as a sign that these firms are still too young and inexperienced to set up a proper appropriability regime and to develop complementary innovative strategies.

5. Concluding remarks

¹⁶ This result is consistent with previous studies (see Conte and Vivarelli, 2005) and is not surprising; indeed, it can be seen as a direct consequence of the sample selection procedure. In fact, MAC is strictly related to process innovation, which is the innovative category excluded in the selected sample. The 615 excluded firms are those only engaged in process innovation, while the 2,098 firms included are those exhibiting either product innovation only or product and process innovation jointly.

This paper has discussed the determinants of innovative output in YICs and mature firms, by looking both at firms' internal and external R&D activities and at the acquisition of external technology in its embodied and disembodied components. These input-output relationships have been tested through a sample selection procedure which takes into account the fact that our measure of innovative performance only refers to product innovation.

Looking at the aggregate results, it turns out that in-house R&D is closely linked to innovative performance, while external R&D does not seem to play a relevant role in Italian manufacturing. However, once the YICs are distinguished from the established firms, in the former internal R&D expenditures no longer play a role in increasing innovation intensity, although they do increase the probability of engaging in product innovation. The crucial innovative input for YICs turns out to be the external acquisition of technology in its embodied component (MAC). This input is also positive and significant with regard to the mature firms, but it more than doubles in the case of the YICs.

These results suggest that in a intermediate-technology context such as Italian manufacturing where middle-tech and traditional sectors represent the core of the industrial structure, on average YICs cannot be considered as NTBFs. Rather, they appear to be entrepreneurial entities which need to acquire external knowledge in order to foster their own innovation activity and are therefore crucially dependent on the external environment.

Acknowledgments

The authors would like to thank Andrea Conte, Giovanni Seri and the ADELE Laboratory at ISTAT in Rome for the provision of CIS 3 data.

References

- Acs, Z.J., Audretsch, D.B., 1988. Innovation in large and small firms: an empirical analysis. *The American Economic Review* 78 (4), 678-690.
- Acs, Z.J., Audretsch, D.B., 1990. *Innovation and Small Firms*. Cambridge, Mass.: MIT Press.
- Acs, Z.J., Audretsch, D.B., Feldman, M.P., 1994. R&D spillovers and recipient firm size. *The Review of Economics and Statistics* 76 (2), 336-340.
- Archibugi, D., Pianta, M., 1992. *The Technological Specialization of Advanced Countries: A Report to the EEC on International Science and Technology Activities*. Boston: Kluwer Academic Publisher.
- Archibugi, D., Iammarino, S., 1999. The policy implications of the globalisation of innovation. *Research Policy* 28 (2-3), 317-336.
- Arrighetti, A., Vivarelli, M., 1999. The role of innovation in the post-entry performance of new small firms: evidence from Italy. *Southern Economic Journal* 65 (4), 927-939.
- Arrow, K., 1962. The economic implications of Learning by Doing. *Review of Economic Studies* 29 (3), 155-173.
- Audretsch, D., Vivarelli, M., 1996. Determinants of new-firm startups in Italy. *Empirica* 23 (2), 91-105.
- Barlet, C., Duguet, E., Encaoua, D., Pradel, J., 2000. The commercial success of innovations: an econometric analysis at the firm level in French manufacturing. In D. Encaoua, B.H. Hall, F. Laisney and J. Mairesse, eds., *The Economics and Econometrics of Innovation*. Boston: Kluwer Academic Publishers, 435-456.
- Bartelsman, E., Haltiwanger, J., Scarpetta, S., 2004. Microeconomic evidence of creative destruction in industrial and developing countries. IZA Discussion Paper No. 1374.
- BEPA, 2008. *Innovation and Growth in the EU: the Role of SME Policy*. Brussels: European Commission.
- Breschi, S., Malerba, F. Orsenigo, L., 2000. Technological regimes and Schumpeterian patterns of innovation. *The Economic Journal* 110 (463), 388-410.
- Bresnahan, T.F., Brynjolfsson, E., Hitt, L.M., 2002. Information technology, workplace organization and the demand for skilled labor: firm-level evidence. *Quarterly Journal of Economics* 117 (1), 339-376.
- Busom, I., 2000. An empirical evaluation of the effects of R&D subsidies. *Economics of Innovation and New Technology* 9 (2), 111-148.

- Cassiman, B., Veugelers, R., 2002. R&D cooperation and spillovers: some empirical evidence from Belgium. *The American Economic Review* 92 (4), 1169-1184.
- Cefis, E., Marsili, O., 2006. Survivor: the role of innovation in firm's survival. *Research Policy* 35 (5), 626-641.
- Cohen, W.M., Klepper, S., 1996. A reprise of size and R&D. *The Economic Journal* 106 (437), 925-951.
- Colombo, M.G., Grilli, L., 2005. Founders' human capital and the growth of New Technology-Based Firms: a competence-based view. *Research Policy* 34 (6), 795-816.
- Conte, A., Vivarelli, M., 2005. One or many knowledge production functions? Mapping innovative activity using microdata. IZA Discussion Paper No. 1878.
- Crépon, B., Duguet, E., Mairesse, J., 1998. Research, innovation and productivity: an econometric analysis at the firm level. *Economics of Innovation and New Technology* 7 (2), 115-158.
- Dosi, G., 1988. Sources, procedures, and microeconomic effects of innovation. *Journal of Economic Literature* 26 (3), 1120-1171.
- Freeman, C., 1982. *The Economics of Industrial Innovation*, 2nd ed. London: Pinter.
- Freeman, C., 1987. *Technology Policy and Economic Performance. Lessons from Japan*. London: Pinter.
- Freeman, C., Clark, J., Soete, L., 1982. *Unemployment and Technical Innovation: A Study of Long Waves in Economic Development*. London: Pinter.
- Freeman, C., Soete, L., 1987. *Technical Change and Full Employment*. London: Basil Blackwell.
- Fritsch, M., Franke, G., 2004. Innovation, regional knowledge spillovers and R&D cooperation. *Research Policy* 33 (2), 245-255.
- Gilbert, R., Newbery, D., 1982. Preemptive patenting and the persistence of monopoly. *The American Economic Review* 72 (3), 514-526.
- González, X., Jaumandreu, J., Pazó, C., 2005. Barriers to innovation and subsidy effectiveness. *The RAND Journal of Economics* 36 (4), 930-949.
- Greenwood, J., Hercowitz, Z., Krusell, P., 1997. Long-run implications of investment-specific technological change. *The American Economic Review* 87 (3), 342-362.
- Griliches, Z., 1979. Issues in assessing the contribution of Research and Development to productivity growth. *The Bell Journal of Economics* 10 (1), 92-116.
- Griliches, Z., 1990. Patent statistics as economic indicators: a survey. *Journal of Economic Literature* 28 (4), 1661-1707.

- Hall, B.H., 1996. The private and social returns to Research and Development. In B.L.R. Smith and C.E. Barfield, eds., *Technology, R&D, and the Economy*. Washington, DC: Brookings Institution and American Enterprise Institute, 140-183.
- Hall, B.H., 2000. Innovation and market value. In R. Barrell, G. Mason and M. O'Mahoney, eds., *Productivity, Innovation and Economic Performance*. Cambridge: Cambridge University Press, 177-198.
- Hall, B.H., Jaffe, A., Trajtenberg, M., 2005. Market value and patent citations. *RAND Journal of Economics* 36 (1), 16-38.
- Hansen, J.A., 1992. Innovation, firm size, and firm age. *Small Business Economics* 4 (1), 37-44.
- Harhoff, D., Scherer, F.M., Vopel, K., 2003. Citations, family size, opposition, and the value of patent rights. *Research Policy* 32 (8), 1343-1364.
- Heckman J., 1979. Sample selection as a specification error. *Econometrica* 47 (1), 153-161.
- Hitt, L.M., Brynjolfsson, E., 2002. Information technology, organizational transformation, and business performance. In N. Greenan, Y. L'Horty, J. Mairesse, eds., *Productivity, Inequality, and the Digital Economy. A Transatlantic Perspective*. Cambridge, MA: MIT Press, 55-91.
- Huergo, E., Jaumandreu, J., 2004. How does probability of process innovation change with firm age. *Small Business Economics* 22 (3-4), 193-207.
- Hulten, C.R., 1992. Growth accounting when technical change is embodied in capital. *The American Economic Review* 82 (4), 964-980.
- ISTAT, 2004. *Statistiche sull'Innovazione delle Imprese. Settore Industria. Anni 1998-2000*, Rome: ISTAT.
- Jorgenson, D.W., 1966. The embodiment hypothesis. *Journal of Political Economy* 74 (1), 1-17.
- Levin, R., Klevorick, A., Nelson, R.R., Winter, S.D., 1987. Appropriating the returns from industrial R&D. *Brookings Papers of Economic Activity* 3, 783-831.
- Lööf, H., Heshmati, A., 2001. On the relationship between innovation and performance: a sensitivity analysis. ECIS – Stockholm School of Economics, Working Paper Series in Economics and Finance No. 446.
- Lööf, H., Heshmati, A., 2002. Knowledge capital and performance heterogeneity: a firm-level innovation study. *International Journal of Production Economics* 76 (1), 61-85.
- Lundvall, B.-Å., 1992. *National Systems of Innovation*. London: Pinter.

- Mairesse, J., Mohnen, P., 2002. Accounting for innovation and measuring innovativeness: an illustrative framework and an application. *The American Economic Review, Papers and Proceedings* 92 (2), 226-230.
- Malerba, F., 1992. Learning by firms and incremental technical change. *Economic Journal* 102 (413), 845-859.
- Malerba, F., 1993. The National System of Innovation: Italy. In R.R. Nelson, ed., *National Systems of Innovation: a Comparative Study*. Oxford: Oxford University Press, 230-260.
- Malerba, F., 2002. Sectoral Systems of Innovation and production. *Research Policy* 31 (2), 247-264.
- Malerba, F., Orsenigo, L., 1996. Schumpeterian patterns of innovation. *Cambridge Journal of Economics* 19 (1), 47-65.
- Narula, R., Zanfei, A., 2003. The international dimension of innovation. In J. Fagerberg, D.C. Mowery and R.R. Nelson, eds., *The Oxford Handbook of Innovation*. Oxford: Oxford University Press, 318-345.
- Nelson, R.R., 1993. *National Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.
- Nelson, R.R., S.G. Winter, 1982. *An Evolutionary Theory of Economic Change*. Harvard: Harvard University Press.
- OECD, 1997. *Oslo Manual: The Measurement of Scientific and Technological Activities. Proposed Guideline for Collecting and Interpreting Technological Innovation Data*. Paris: OECD.
- Parisi, M.L., Schiantarelli, F., Sembenelli, A., 2006. Productivity, innovation and R&D: micro evidence for Italy. *European Economic Review* 50 (8), 2037-2061.
- Patel, P., Pavitt, K., 1995. Patterns of technological activity: their measurement and interpretation. In P. Stoneman, ed., *Handbook of the Economics of Innovation and Technological Change*. Oxford: Blackwell Publishers, 14-51.
- Pavitt, K., 1984. Sectoral patterns of technical change: towards a taxonomy and a theory. *Research Policy* 13 (6), 343-373.
- Piga, C.A., Vivarelli, M., 2003. Sample selection in estimating the determinants of cooperative R&D. *Applied Economics Letters* 10 (4), 243-246.
- Piga, C.A., Vivarelli, M., 2004. Internal and external R&D: a sample selection approach. *Oxford Bulletin of Economics and Statistics* 66 (4), 457-482.

- Piva, M., Santarelli, E., Vivarelli, M., 2005. The skill bias effect of technological and organisational change: evidence and policy implications. *Research Policy* 34 (2), 141-157.
- Salter, W.E.G., 1960. *Productivity and Technical Change*. Cambridge: Cambridge University Press.
- Santamaría, L., Nieto, M.J., Barge-Gil, A., 2009. Beyond formal R&D: taking advantage of other sources of innovation in low-and medium-technology industries. *Research Policy* 38 (3), 507-517.
- Santarelli, E., Sterlacchini, A., 1990. Innovation, formal vs. informal R&D, and firm size: some evidence from Italian manufacturing firms. *Small Business Economics* 2 (2), 223-228.
- Santarelli, E., Vivarelli, M., 2007. Entrepreneurship and the process of firms' entry, survival and growth. *Industrial and Corporate Change* 16 (3), 455-488.
- Schneider, C., Veugelers, R., 2008. On young innovative companies: why they matter and how (not) to policy support them. Department of Economics, Copenhagen Business School Working Paper 4-2008.
- Schumpeter, J.A., 1934. *The Theory of Economic Development*. Cambridge, Mass.: Harvard University Press.
- Schumpeter, J.A., 1942. *Capitalism, Socialism and Democracy*. New York: Harper and Brothers.
- Storey, D.J., Tether, B.S., 1998. New Technology-Based Firms in the European Union: an introduction. *Research Policy* 26 (9), 933-946.
- Wallsten, S.J., 2000. The effects of government-industry R&D programs on private R&D: the case of the Small Business Innovation Research Program. *The RAND Journal of Economics* 31 (1), 82-100.
- Winter, S.G., 1984. Schumpeterian competition in alternative technological regimes. *Journal of Economic Behavior and Organization*, 5 (3), 287-320.

Table 1: The variables

| | |
|---|---|
| <i>Innovative input variables</i> | |
| IRint | Internal R&D expenditure in 2000, normalized by total turnover |
| ERint | External R&D expenditure in 2000, normalized by total turnover |
| MACint | Investments in innovative machinery and equipment in 2000, normalized by total turnover |
| TAint | Technological acquisitions in 2000, normalized by total turnover |
| <i>Innovative output variables</i> | |
| TURNIN | Share of firm's total sales due to sale of new products |
| PROD | Product innovation: dummy = 1 if TURNIN > 0 |
| <i>Firm's general characteristics</i> | |
| EXPint | Export intensity ((turnover from export) / turnover) |
| IG | Dummy = 1 if belonging to an industrial group |
| <i>Innovative-relevant information</i> | |
| SUPPORT | Dummy = 1 if the firm has received public support for innovation |
| COOP | Dummy = 1 if the firm takes part in cooperative innovative activities |
| PATENT | Dummy = 1 if the firm uses patents |
| PROT | Dummy = 1 if the firm adopts other instruments of protection than patents |
| HURDLE | Dummy = 1 if the firm has faced some kind of obstacle to innovation |
| OTHERIN | Dummy = 1 if the firm has realized managerial, strategic or organizational innovation |
| <i>Pavitt sectoral dummies</i> | |
| SB | Dummy = 1 if science-based firm |
| SI | Dummy = 1 if scale intensive firm |
| SS | Dummy = 1 if specialized supplier firm |
| SD | Dummy = 1 if supplier-dominated firm |

Table 2: Descriptive statistics

| | ALL FIRMS | | | | MATURE FIRMS | | | | YOUNG FIRMS (YICs) | | | |
|--|-----------|--------|-----------|--------|--------------|--------|-----------|--------|--------------------|--------|---------|--------|
| | 2,713 OBS | | 2,098 OBS | | 2,420 OBS | | 1,870 OBS | | 293 OBS | | 228 OBS | |
| | MEAN | SD | MEAN | SD | MEAN | SD | MEAN | SD | MEAN | SD | MEAN | SD |
| <i>Innovative input variables</i> | | | | | | | | | | | | |
| IRint | 0.013 | 0.026 | 0.015 | 0.028 | 0.013 | 0.025 | 0.015 | 0.027 | 0.014 | 0.032 | 0.017 | 0.036 |
| ERint | 0.002 | 0.009 | 0.002 | 0.010 | 0.002 | 0.008 | 0.002 | 0.009 | 0.002 | 0.011 | 0.003 | 0.013 |
| MACint | 0.035 | 0.078 | 0.028 | 0.067 | 0.034 | 0.076 | 0.027 | 0.063 | 0.042 | 0.091 | 0.038 | 0.093 |
| TAint | 0.002 | 0.018 | 0.002 | 0.015 | 0.002 | 0.017 | 0.002 | 0.013 | 0.004 | 0.023 | 0.004 | 0.025 |
| <i>Innovative output variables</i> | | | | | | | | | | | | |
| TURNIN | 30.260 | 29.364 | 39.131 | 27.710 | 29.781 | 29.982 | 38.541 | 27.375 | 34.218 | 32.129 | 43.973 | 29.949 |
| PROD (<i>dummy</i>) | 0.773 | 0.419 | 1 | 0 | 0.773 | 0.419 | 1 | 0 | 0.778 | 0.416 | 1 | 0 |
| <i>Firm's general characteristics</i> | | | | | | | | | | | | |
| EXPint | 0.254 | 0.285 | 0.278 | 0.290 | 0.259 | 0.286 | 0.283 | 0.290 | 0.215 | 0.279 | 0.235 | 0.286 |
| IG (<i>dummy</i>) | 0.291 | 0.454 | 0.318 | 0.466 | 0.290 | 0.454 | 0.318 | 0.466 | 0.300 | 0.459 | 0.316 | 0.466 |
| <i>Innovative-relevant information</i> | | | | | | | | | | | | |
| SUPPORT (<i>dummy</i>) | 0.533 | 0.499 | 0.539 | 0.499 | 0.533 | 0.499 | 0.536 | 0.499 | 0.536 | 0.499 | 0.566 | 0.497 |
| COOP (<i>dummy</i>) | 0.161 | 0.368 | 0.192 | 0.394 | 0.162 | 0.369 | 0.193 | 0.395 | 0.150 | 0.358 | 0.180 | 0.385 |
| PATENT (<i>dummy</i>) | 0.348 | 0.476 | 0.413 | 0.492 | 0.354 | 0.478 | 0.420 | 0.494 | 0.293 | 0.456 | 0.360 | 0.481 |
| PROT (<i>dummy</i>) | 0.679 | 0.467 | 0.756 | 0.430 | 0.683 | 0.465 | 0.758 | 0.428 | 0.642 | 0.480 | 0.737 | 0.441 |
| HURDLE (<i>dummy</i>) | 0.402 | 0.490 | 0.424 | 0.494 | 0.397 | 0.489 | 0.418 | 0.493 | 0.440 | 0.497 | 0.474 | 0.500 |
| OTHERIN (<i>dummy</i>) | 0.841 | 0.365 | 0.886 | 0.318 | 0.838 | 0.369 | 0.884 | 0.320 | 0.874 | 0.333 | 0.899 | 0.302 |
| <i>Pavitt sectoral dummies</i> | | | | | | | | | | | | |
| SB (<i>dummy</i>) | 0.116 | 0.320 | 0.134 | 0.341 | 0.113 | 0.316 | 0.130 | 0.337 | 0.140 | 0.347 | 0.167 | 0.373 |
| SI (<i>dummy</i>) | 0.284 | 0.451 | 0.250 | 0.433 | 0.282 | 0.450 | 0.248 | 0.432 | 0.300 | 0.459 | 0.267 | 0.444 |
| SS (<i>dummy</i>) | 0.280 | 0.449 | 0.314 | 0.464 | 0.282 | 0.450 | 0.318 | 0.466 | 0.266 | 0.443 | 0.285 | 0.452 |
| SD (<i>dummy</i>) | 0.320 | 0.466 | 0.301 | 0.459 | 0.323 | 0.468 | 0.304 | 0.460 | 0.293 | 0.456 | 0.281 | 0.450 |

Table 3: The sample selection estimates

| | ALL FIRMS | | MATURE FIRMS | | YICs | |
|-----------------|---------------------|---------------------|---------------------|---------------------|-------------------|--------------------|
| | PROD | TURNIN | PROD | TURNIN | PROD | TURNIN |
| Constant | -0.19** (-2.13) | 16.32*** (3.01) | -0.16* (-1.79) | 19.91*** (3.60) | -0.25 (-0.83) | 11.97 (0.85) |
| IRint | 15.17*** (7.20) | 128.87*** (4.62) | 15.23*** (6.91) | 128.32*** (4.29) | 14.42* (1.90) | 79.93 (1.16) |
| ERint | 7.75 (1.24) | 25.89 (0.37) | 8.47 (1.25) | -1.26 (-0.02) | 2.59 (0.14) | 135.70 (0.79) |
| MACint | -1.11*** (-3.23) | 31.62*** (3.07) | -1.38*** (-3.61) | 26.78** (2.32) | 0.19 (0.20) | 68.25*** (3.03) |
| TAint | -0.32 (-0.20) | -35.37 (-0.87) | -0.25 (-0.15) | -68.99 (-1.47) | -0.90 (-0.21) | 37.25 (0.43) |
| EXPint | 0.10 (0.89) | 2.98 (1.29) | 0.11 (0.93) | 1.54 (0.65) | 0.04 (0.11) | 16.83** (2.14) |
| IG | 0.01 (0.19) | | 0.02 (0.24) | | -0.11 (-0.48) | |
| SUPPORT | -0.09 (-1.43) | | -0.13** (-2.00) | | 0.38* (1.88) | |
| COOP | 0.37*** (3.55) | 3.30* (1.86) | 0.38*** (3.39) | 2.99* (1.65) | 0.53 (1.44) | 1.49 (0.25) |
| PATENT | 0.48*** (6.21) | | 0.47*** (5.85) | | 0.66** (2.20) | |
| PROT | 0.46*** (6.95) | 5.34** (2.41) | 0.43*** (6.12) | 4.68** (2.11) | 0.72*** (3.50) | 5.68 (0.75) |
| HURDLE | -0.01 (-0.09) | -2.05 (-1.60) | -0.022 (-0.34) | -2.80** (-2.11) | 0.08 (0.39) | 2.44 (0.57) |
| OTHERIN | 0.42*** (5.47) | 6.98*** (2.97) | 0.45*** (5.54) | 6.18** (2.52) | 0.15 (0.58) | 5.28 (0.76) |
| SB | 0.18 (1.46) | 8.25*** (3.67) | 0.13 (1.03) | 6.12*** (2.63) | 0.56 (1.38) | 19.75*** (2.81) |
| SI | -0.08 (-1.20) | -0.10 (-0.06) | -0.08 (-1.13) | 0.09 (0.05) | -0.26 (-1.15) | -0.61 (-0.11) |
| SS | 0.35*** (4.41) | 7.45*** (4.05) | 0.37*** (4.30) | 6.68*** (3.53) | 0.20 (0.80) | 6.74 (1.18) |
| ρ | | 0.62 | | 0.48 | | 0.85 |
| Mills λ | | 18.04*** (2.98) | | 13.57** (2.19) | | 27.20* (1.75) |
| N. of firms | 2,713 | 2,098 | 2,420 | 1,870 | 293 | 228 |

Notes:

- z-statistics in parentheses: * Significant at 10%; ** 5%; *** 1% .

Appendix A1: Sectoral composition and average employment of the firms belonging to the two subsamples: YICs and Mature firms.

| INDUSTRY | YICs | | | MATURE FIRMS | | |
|---|-------------|------|----------|--------------|------|----------|
| | N. of firms | % | Av. Emp. | N. of firms | % | Av. Emp. |
| Manufacture of food products and beverage | 14 | 4.8 | 136 | 152 | 6.3 | 210 |
| Manufacture of textiles | 13 | 4.4 | 107 | 110 | 4.5 | 205 |
| Manufacture of wearing apparel; dressing and dyeing of fur | 6 | 2.0 | 47 | 43 | 1.8 | 131 |
| Manufacture of leather and related products | 7 | 2.4 | 73 | 58 | 2.4 | 83 |
| Manufacture of wood and of products of wood and cork, exc. furniture | 9 | 3.1 | 26 | 80 | 3.3 | 55 |
| Manufacture of paper and paper products | 8 | 2.7 | 65 | 72 | 3.0 | 89 |
| Printing and reproduction of recorded media | 10 | 3.4 | 34 | 124 | 5.1 | 97 |
| Manufacture of coke and refined petroleum products | 5 | 1.7 | 139 | 18 | 0.7 | 52 |
| Manufacture of chemicals and chemical products | 27 | 9.2 | 191 | 200 | 8.3 | 189 |
| Manufacture of rubber and plastics products | 15 | 5.1 | 62 | 151 | 6.2 | 128 |
| Manufacture of other non-metallic mineral products | 17 | 5.8 | 37 | 152 | 6.3 | 173 |
| Manufacture of basic metals | 18 | 6.1 | 133 | 94 | 3.9 | 335 |
| Manufacture of fabricated metal products | 26 | 8.9 | 79 | 194 | 8.0 | 115 |
| Manufacture of machinery and mechanical equipment | 37 | 12.6 | 197 | 292 | 12.1 | 252 |
| Manufacture of office machinery and computers | 7 | 2.4 | 26 | 33 | 1.4 | 82 |
| Manufacture of electrical equipment | 13 | 4.4 | 96 | 154 | 6.4 | 174 |
| Manufacture of radio, television and communication equipment | 9 | 3.1 | 277 | 97 | 4.0 | 222 |
| Manufacture of medical, precision and optical instruments | 23 | 7.8 | 118 | 126 | 5.2 | 75 |
| Manufacture of motor vehicles, trailers and semi-trailers | 11 | 3.8 | 77 | 84 | 3.5 | 460 |
| Manufacture of other transport equipment | 8 | 2.7 | 73 | 49 | 2.0 | 646 |
| Other manufacturing | 8 | 2.7 | 53 | 124 | 5.1 | 91 |
| Waste collection, treatment and disposal activities; materials recovery | 2 | 0.7 | 15 | 13 | 0.5 | 17 |
| SAMPLE | 293 | 100 | | 2,420 | 100 | |

Appendix A2: Correlation matrix (overall sample: 2,713 firms).

| | PROD | IRint | ERint | MACint | TAint | EXPint | OTHERIN | IG | SUPPORT | COOP | PATENT | PROT | HURDLE |
|---------|--------|--------|--------|--------|--------|--------|---------|--------|---------|--------|--------|--------|--------|
| PROD | 1.000 | | | | | | | | | | | | |
| IRint | 0.186 | 1.000 | | | | | | | | | | | |
| ERint | 0.093 | 0.245 | 1.000 | | | | | | | | | | |
| MACint | -0.159 | -0.069 | -0.046 | 1.000 | | | | | | | | | |
| TAint | -0.007 | 0.026 | 0.044 | 0.034 | 1.000 | | | | | | | | |
| EXPint | 0.160 | 0.050 | 0.041 | -0.167 | -0.037 | 1.000 | | | | | | | |
| OTHERIN | 0.223 | 0.062 | 0.049 | -0.093 | 0.027 | 0.163 | 1.000 | | | | | | |
| IG | 0.110 | 0.024 | 0.057 | -0.115 | -0.008 | 0.243 | 0.109 | 1.000 | | | | | |
| SUPPORT | 0.021 | 0.178 | 0.061 | 0.060 | 0.003 | 0.055 | 0.031 | 0.000 | 1.000 | | | | |
| COOP | 0.156 | 0.173 | 0.168 | -0.074 | 0.014 | 0.159 | 0.105 | 0.249 | 0.118 | 1.000 | | | |
| PATENT | 0.253 | 0.096 | 0.102 | -0.141 | 0.020 | 0.304 | 0.171 | 0.241 | 0.055 | 0.196 | 1.000 | | |
| PROT | 0.306 | 0.150 | 0.099 | -0.134 | -0.003 | 0.240 | 0.311 | 0.185 | 0.059 | 0.186 | 0.370 | 1.000 | |
| HURDLE | 0.083 | 0.100 | 0.091 | -0.018 | 0.036 | 0.048 | 0.139 | 0.000 | 0.002 | 0.093 | 0.116 | 0.152 | 1.000 |
| SB | 0.108 | 0.234 | 0.220 | -0.054 | 0.001 | 0.048 | 0.059 | 0.050 | 0.019 | 0.127 | 0.135 | 0.140 | 0.051 |
| SI | -0.139 | -0.077 | -0.090 | 0.107 | 0.017 | -0.149 | -0.073 | -0.015 | 0.008 | -0.031 | -0.121 | -0.126 | -0.058 |
| SS | 0.138 | 0.065 | 0.037 | -0.094 | -0.024 | 0.154 | 0.010 | 0.041 | 0.031 | 0.077 | 0.114 | 0.059 | 0.042 |
| SD | -0.073 | -0.149 | -0.100 | 0.024 | 0.006 | -0.038 | 0.020 | -0.059 | -0.051 | -0.130 | -0.086 | -0.031 | -0.020 |

