JRC Technical Notes

IPTS WORKING PAPER on
CORPORATE R&D AND INNOVATION - No. 05/2010

Profits, R&D and Innovation: a Model and a Test

Francesco Bogliacino and Mario Pianta

May 2010

JRC EUROPEAN COMMISSION

ipts Institute for Prospective Technological Studies

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These *IPTS Working Papers on Corporate R&D and Innovation* can take the form of more *policy oriented notes*, mainly addressed to EU policy-makers. They present policy implications derived from our own research and the views of the most prominent authors in the field, making the appropriate references.

The main authors of this paper are Francesco Bogliacino (European Commission, Joint Research Center- Institute for Prospective Technological Studies, Sevilla; Centro de Estudios Para America Latina y el Caribe-Universidad EAFIT, Rise Group, Medellin) and Mario Pianta (University of Urbino and Lunaria). This work has been a development from the technical report written for the EIS Project - European Commission and MERIT under the PRO-INNO initiative by Directorate General Enterprise and Industry, to whom we are grateful for their financial support. We thank Daniele Archibugi, Andries Brandsma, Dilek Çetin, Michele Cincera, Andrea Conte, Andrea Filippetti, Hugo Hollanders, Pietro Moncada-Paternò-Castello, Carlos Montalvo, Raquel Ortega-Argilés and Keith Sequeira for their comments and advice. On the last version we have appreciated the insights suggested by Franco Malerba, Maurizio Franzini and all the participants to the Conference "Innovation and Entrepreneurship in the Knowledge-Based Society" in Milan and to the "Imprese, Innovazione, Politiche" Workshop at the University of "Roma Tre in Rome". The usual disclaimer applies. The text of the integral report is available on the PRO-INNO website and can be downloaded from: http://www.proinno-europe.eu/node/admin/uploaded_documents/MERITBogliacinoPiantaFINAL.pdf.

The *IPTS Working Papers on Corporate R&D and Innovation* are published under the editorial responsibility of Pietro Moncada-Paternò-Castello, Andries Brandsma, Michele Cincera and Enrico Santarelli at the Knowledge for Growth Unit – Economics of Industrial Research and Innovation Action of IPTS / Joint Research Centre of the European Commission.

Contact information - P. Moncada-Paternò-Castello
European Commission, Joint Research Centre - Institute for Prospective Technological Studies
Edificio Expo
C/ Inca Garcilaso, 3
E-41092 Seville (Spain)
Fax: +34 95 448 83 00; E-mail: jrc-ipts-kfg-secretariat@ec.europa.eu
IPTS website: http://ipts.jrc.ec.europa.eu/; JRC website: http://www.jrc.ec.europa.eu
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IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 05/2010
Full electronic version of the paper can be downloaded at http://iri.jrc.es/

JRC58871
EUR 24325 EN/5
ISBN 978-92-79-16242-8
ISSN 1018-5593
ISSN 1831-872X
doi:10.2791/44497

Luxembourg: Publications Office of the European Union

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Printed in Spain

Abstract

In this article we investigate – both conceptually and empirically – the relationship between three interconnected elements of the Schumpeterian "engine of progress": the ability of industries' R&D efforts to turn out successful innovations; the ability of innovations to lead to high entrepreneurial profits; the commitment of industries to invest profits in further technological efforts. We build a simultaneous three-equation model – with appropriate lags – and we test it at industry level – for 38 manufacturing and service sectors – on eight European countries over two time periods from 1994 to 2006. The results show that the model effectively accounts for the dynamics of European industries.

Our main results are that demand and innovation are the key determinants for firm profitability; second that both technology adoption and R&D concur to improve innovative performance; third, that R&D is path dependent and is negatively related to the distance from the frontier. Finally, manufacturing and services show similar behaviour.

JEL Classification: L6, L8, O31, O33, O52

Keywords: Profits, R&D, Innovation, System Two Stages Least Squares

1 Introduction

The process of innovation is at the core of the Schumpeterian view of economic change whereby successful "new combinations" - new products, processes, organisations, markets and sources of inputs - are introduced, leading to new economic activities, "creative destruction" and entrepreneurial profits protected by temporary monopoly power (Schumpeter 1934). As competitive markets are replaced by large firms and oligopolistic structures[1], innovative efforts are institutionalised in R&D activities and "technological progress is increasingly becoming the business of teams of trained specialists who turn out what is required and make it work in predictable ways" (Schumpeter, 1942, 1976 edn. p.132). In this way, [the large-scale establishment] "has come to be the most powerful engine of that progress and in particular of the long-run expansion of total output" (ibid. p.106).

In order for such an "engine of progress" to work, however – alongside the presence of favourable external conditions in markets and institutions – a coherence is needed between three distinct processes: the ability of industries' R&D efforts to turn out successful innovations; the ability of innovations to lead to high entrepreneurial profits; the commitment of industries to invest such profits in further technological efforts. In this article we explore – both conceptually and empirically – the existence of such a "virtuous circle".

Recent studies have generally addressed these links in separate ways. A major contribution has come from Crepon, Duguet and Mairesse (1998) who have proposed a widely tested model where R&D leads to innovation, and innovation leads to productivity improvements (applications of this approach are in Mairesse and Mohnen, 2001, 2002; Parisi et al. 2006). More traditional approaches have linked R&D or patent data to different measures of productivity (Bottazzi and Peri, 2007; Crafts and Mills, 2006; Lanjouw and Schankerman, 2004; Bloom and Van Reenen, 2002).

Studies on the relationship between innovation and profits have often moved from a view of profit seeking as the motivation behind investment in innovation and technology, both in industry models (Klepper, 1997) and in studies of firms (Teece, 1986, Geroski, Machin and Van Reenen, 1993, Cefis and Ciccarelli, 2005). The impact of innovation on profits and wages is also examined in Pianta and Tancioni (2008). Few works have addressed the influence that profits have on R&D efforts in firms and industries (Hall, 2002; O'Sullivan, 2005).

Our aim in this article is to address all these relationships in an integrated and coherent way, considering not just one-way relationships, but the feedback loops and cumulative processes that shape the evolution of industries in the long term. We develop a simultaneous model – with the appropriate lag structure - where R&D can lead to innovation, innovation brings in profits and profits sustain R&D efforts. The model is tested at the industry level – 38 manufacturing and service sectors – on eight European countries over two time periods from 1994 to 2006.

The article explores in section 2 the links between R&D, innovation and profits, proposing a model for understanding their relationship. Data and methodology are presented in section 3; results are discussed in section 4; conclusions follow.

[1] "The introduction of new methods of production and new commodities is hardly conceivable with perfect (...) competition from the start. And this means that the bulk of what we call economic progress is incompatible with it" (Schumpeter, 1942, 1976 edn. p.105).

2 The links between profits, R&D efforts and innovation performance

In our model, we build on three perspectives of analysis. First, we focus on profits as they are – at the same time - a specific measure of innovation-driven entrepreneurial success (in a Schumpeterian vein); an indicator of successful performance (parallel to productivity measures); the source for supporting R&D and innovative efforts. We conceptualise profit growth as the outcome of innovation on the supply side, and of market growth on the demand side. In this way we move beyond the one-sided perspective typical of innovation-performance studies that tend to neglect the role of demand; building on previous studies on the role of final demand components in innovation and performance (Crespi and Pianta, 2007, 2008), we proxy demand dynamics with value added growth.

The second perspective is that of R&D and innovation studies. We consider R&D as the main input for innovative efforts, but we move beyond reliance on R&D and patents alone as technology indicators and make extensive use of innovation surveys measuring different dimensions of innovative efforts (Archibugi and Pianta, 1996; Smith, 2005; Eurostat, 2008). This makes it possible to conceptualise and test the link between technological capacity and efforts (proxied by R&D) and their effective market outcomes (proxied by the share of sales due to innovative products).

The R&D-innovation-productivity links have often been investigated using the approach proposed by Crepon et al. (1998)[2] that provides an explanation of the innovation process by breaking it down into: a) the decision to carry out an expenditure effort; b) the relation between a single and undifferentiated innovative input (R&D) and output, c) the impact of innovation output on economic performance (usually productivity). In this article we improve on such literature in three directions. First, we develop a more complex view of innovation; building on the evidence of innovation surveys. We consider the variety of innovative strategies, making a distinction between a search for technological competitiveness through knowledge generation, product innovation and expansion of new markets, as well as efforts to improve cost competitiveness through new labour saving processes, technology acquisition from suppliers and restructuring. In our model we will include these two dimensions of innovative activities (Pianta, 2001; Bogliacino and Pianta, 2009b,2010).[3] Second, we avoid being confined to supply side mechanisms alone by also considering the dynamics of demand, proxied by value added growth. Third, we introduce in the model a temporal structure, with the presence of cumulative and feedback effects. Profits are the outcome of innovative efforts and the main driver of it, as they provide the necessary financial resources.

The third perspective that supports our model is the neo-Schumpeterian literature on technological trajectories, technology regimes and sectoral innovation systems (Dosi, 1982,1988; Breschi et al. 2000, Malerba, 2002, 2004) that has emphasised the cumulative nature of technological change, the challenges for innovating at the technological frontier, the role of demand pull factors in innovation and the importance of large firms. We model R&D efforts (in terms of R&D expenditure per employee) in a way that includes such aspects, as

[2] For a previous contribution, with single equation structure see Geroski et al. (1993). See also Parisi et al. (2006).
[3] A wide range of studies have shown that the former strategy is related to strong R&D efforts and patent applications, widespread introduction of new products, high shares of turnover from new products, an aim to open new markets and a relevance of clients as sources of innovation. The latter is related to high machinery expenditures, widespread introduction of new processes, an aim to reduce labour costs and increase flexibility, and the relevance of suppliers as sources of innovation (Pianta, 2001; Crespi and Pianta, 2007, 2008; Bogliacino and Pianta, 2009b,2010).

well as the growth of (lagged) profits that are expected to fund R&D activities (Hall, 2002; O'Sullivan, 2005).

Such literature has stressed the specificity of industries in terms of their innovation patterns and growth trajectories, but has generally focused on manufacturing alone: a major novelty of our work is the consideration of both manufacturing and services in the empirical analysis.[4] Moreover, an analysis at the industry level – as opposed to one on panels of firms – has the advantage of accounting for the totality of changes in the economy and of considering the constraint posed by demand. Growing firms may expand by "stealing business" from declining firms; conversely, at the industry level there is an aggregate demand constraint set by the overall increase of value added.

We are now in the position to develop a simultaneous model with feedback loops that integrates different streams of theory in explaining the dynamics of profits, R&D and innovation. Let us now consider the three equations in turn.

2.1. The Profits Equation

Our first equation concerns the determinants of profits. We include a supply variable, related to technology and a demand one. The baseline model is an error component one:

$$\log(\pi_{ijt}) = \alpha_0 + \alpha_1 \log(d_{jit}) + \alpha_2 \log(IP_{ijt-1}) + u_{ij} + \varepsilon_{ijt} \qquad (1)$$

where *i* stands for industry, *j* for country and *t* for time. *d* represents demand, while *IP* stands for innovative performance. As usual we are assuming that technology openly displays its effect with a time lag, in accordance with Schumpeterian perspective. Differentiating in order to eliminate the individual time invariant effect, we get

$$\Delta \log(\pi_{ijt}) = \alpha_1 \Delta \log(d_{jit}) + \alpha_2 \Delta \log(IP_{ijt-1}) + \Delta\varepsilon_{ijt} \qquad (2)$$

We use the average rate of change of operating surplus as a proxy for the rate of change of profits, and the rate of change of value added as a proxy for the rate of change of demand. Finally we use the variation in the share of innovative turnover (between two CIS waves) -ΔIT- as a proxy for the rate of change in innovative performance. The final estimated equation, the first one in our system, is:

$$OS_{ijt} = \alpha_1 VA_{jit} + \alpha_2 \Delta IT_{ijt-1} + \Delta\varepsilon_{ijt} \qquad (3)$$

where *OS* is the compound annual rate of change in operating surplus from *t-1* to *t* and *VA* the compound annual rate of change of value added.

Therefore, the growth of profits (operating surplus, in real terms) is explained by the relevance of lagged innovative sales (a measure of Schumpeterian profits), and by the growth of demand (a measure of market expansion, proxied by the change in industry value added).[5]

[4] In European countries market services represent the largest sector of economic activity and have shown an innovative behaviour that is not so different from manufacturing industries (see Bogliacino and Pianta, 2009a,b, 2010; Crespi and Pianta, 2007, 2008; Miles, 2005; Evangelista and Savona, 2003; Pianta and Tancioni, 2008).

[5] In explaining profit *growth* we believe that Schumpeter's "entrepreneurial profits" are crucial and that the *stock* of capital is likely to play a minor, and sometimes confusing role. In the value of the capital stock, very different elements are mixed up, including an evaluation of financial and real estate assets that are prone to bubbles and

Once got rid of the fixed effect, we still have to address the problem of uneven size grouped data, due to the industry dimension of the single observation. Grouping data of unequal size affects consistency of OLS, thus we have to introduce a weighting procedure, using Weighted Least Squares (WLS), with weights given by employees.

2.2. The Innovation Performance Equation

The second equation is a Cobb-Douglas specification of technological capabilities (*CAP*), as a function of the R&D stock (*Z* in our notation) - *i.e.* internal innovative capabilities -, the stock of external technological acquisition (in terms of machinery, equipment, intermediate products, indicated as *K*) and demand:

$$\log(CAP_{ijt}) = \beta_0 + \beta_1 \log(d_{jit}) + \beta_2 \log(Z_{ijt}) + \beta_3 \log(K_{ijt}) + v_{ij} + \eta_{ijt} \quad (4)$$

Taking again the first difference in order to eliminate time invariant effects, we get:

$$\Delta \log(CAP_{ijt}) = \beta_1 \Delta \log(d_{jit}) + \beta_2 \Delta \log(Z_{ijt-1}) + \beta_3 \Delta \log(K_{ijt-1}) + \Delta \eta_{ijt} \quad (5)$$

We interpret the change in innovation capabilities as a measure of innovative performance that is proxied with the share of sales related to new products (innovative turnover). We proxy the rate of change in R&D stock with the flow of R&D expenditure (RD - we calculate the expenditure per employee since we are working with industry level data). In order to measure technological acquisition we use the share of firms who indicate suppliers as a source of innovation (*SSUP*).[6] Finally, we use again the annual rate of change of value added to measure change in demand.

$$IT_{ijt} = \beta_1 VA_{jit} + \beta_2 RD_{ijt} + \beta_3 SSUPP_{ijt} + \Delta \eta_{ijt} \quad (6)$$

Summing up, in the second equation to be included in our system (6), the share of innovative turnover as a measure of innovative performance[7] is explained by supply-side efforts for improving technological competitiveness (proxied by R&D per employee) and for improving cost competitiveness (proxied by the relevance of suppliers of machinery and intermediate inputs in the sources of innovation), and by the growth of demand (proxied by the change in industry value added).

2.3. The R&D Equation

Finally, in the spirit of Crepon et al. (1998) and Parisi et al (2006), we consider an equation for R&D expenditure. Passing through the same step as before, we formulate it in first differences to eliminate the fixed effects:

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with little relation to their effective contribution to production and growth. Moreover, reliable data on the capital stock at the industry level for manufacturing and services are not available for empirical tests.

[6] We prefer this variable to expenditure for new machinery because the empirical evidence of CIS data for the latter does not allow a clear distinction between investment related to new dynamic activities and labour saving processes associated to restructuring and decline. For details, see Pianta and Bogliacino (2009a).

[7] The share of turnover from new or improved products is a censored variable; however, there is no mass probability neither in zero nor in 100% (there are no observations in the two bounds), so there is no problem in using a linear formulation.

$$\Delta \log(Z_{ijt}) = \gamma_1 \Delta \log(Z_{ijt-1}) + \gamma_2 MK_{jit} + \gamma_3 FR_{ijt} + \gamma_4 SIZE_{ijt} + \gamma_5 \Delta \log(\pi_{jit-1}) + \Delta e_{ijt} \qquad (7)$$

The baseline equation is a relation expressing the change in R&D stock (that we proxy with the flow of R&D expenditure) as an autoregressive, path dependent process shaped by previous R&D, which relies on internal financial resources – lagged profits - because of the difficulty to raise the necessary funds on the financial market, due to the specificity of innovation risks (Hall, 2002). We assume that R&D efforts are related to a set of industry characteristics that reflect structure and strategy: the market expansion objective of innovations - the share of firms innovating in order to enter new markets (MK) -, the average firm size in the sector (SIZE),[8] and a measure of the distance from the technological frontier, as the need to carry out R&D is greater when the opportunities for imitating technology leaders are lower (Dosi, 1988). The "catching up" indicator we use is calculated as the percentage distance of industry labour productivity from the highest value for the same industry in the sample (i.e. among the eight European countries considered). The formal definition can be found in (9):

$$FR_{ijt} = \frac{\left| LP_{ijt} - LP_{i,j\max,t} \right|}{LP_{ijt}} 100$$
$$i \in NACE, \quad j \in \{DE, ES, FR, IT, NL, PT, UK, NO\} \qquad (8)$$
$$j\max = j \; s.t. \; LP_{i,j\max,t} \geq LP_{i,k,t} \quad \forall k$$

When there is a large distance from the productivity frontier – and wide opportunities for "catching up" -, there is room for improving efficiency through technology acquisition and imitation, and there is less pressure to carry out R&D to expand the frontier of knowledge and achieve competitive advantages.

Summing up, our R&D equation proxies the rate of change of R&D stock through the flow of expenditure per employee, as in equation (6), and considers the effects of lagged R&D, lagged profit growth, the search for new markets, firm size and distance from the productivity frontier:`

$$RD_{ijt} = \gamma_1 RD_{ijt-1} + \gamma_2 MK_{ijt} + \gamma_3 FR_{ijt} + \gamma_4 SIZE_{ijt} + \gamma_5 OS_{jit-1} + \Delta e_{ijt} \qquad (9)$$

In the last equation, the lag in R&D flow is endogenous with regards to the disturbance term, by construction (they both include e_{ijt-1}). However, also the catching-up variable can be argued to be endogenous, being related to R&D because of learning mechanisms: R&D improves the capabilities of firms, making them discover new opportunities. The excluded instruments are: the rate of change of demand, the usual country dummies[9] and the lag of *SSUP*.

[8] The concentration of R&D expenditure in larger firms is well known; smaller firms develop technology internally using mainly other activities - from design to production engineering - and acquire knowledge, inputs and machinery from external sources. On this Schumpeterian debate see Cohen and Levine (1989). This variable is assumed to reflect also the market structure of industries, showing the relevance of oligopolistic power associated with the presence of larger firms. More generally, also in the other equations, we assume that market structure is endogenous to the patterns of Schumpeterian innovation and therefore need not be included separately as an independent variable.

[9] Due to the limitation of our time span, we cannot use the time dummies that are dropped as collinear with the constant in the first stage regression.

The full system is:

$$\begin{cases} OS_{ijt} = \alpha_1 VA_{jit} + \alpha_2 \Delta IT_{ijt-1} + \Delta\varepsilon_{ijt} \\ IT_{ijt} = \beta_1 VA_{jit} + \beta_2 RD_{ijt} + \beta_3 SSUPP_{ijt} + \Delta z_{ijt} \\ RD_{ijt} = \gamma_1 RD_{ijt-1} + \gamma_2 MK_{ijt} + \gamma_3 FR_{ijt} + \gamma_4 SIZE_{ijt} + \gamma_5 OS_{jit-1} + \Delta e_{ijt} \end{cases} \quad (10)$$

2.4. Expected results

In considering the three equations as a system, we test the following main hypotheses. First, the dynamics of profits is positively affected by success in (lagged) innovation performance on the supply side, and by strong (simultaneous) demand growth, proxied by value added.

Second, the innovation performance – proxied by innovative sales – is the result of R&D efforts, capturing the search for technological competitiveness, associated to knowledge advances and new products. We also consider the adoption of new technology through suppliers, reflecting a cost competitiveness strategy which, however, may result in greater efficiency and lower jobs, rather than in higher innovative sales. Also the role of demand is not obvious: on the one hand it may support the growth of innovative turnover through the expansion of markets, offering greater opportunities for the success of new products; on the other hand a strong demand growth may reduce the competitive pressure to innovate, as even non-innovators can maintain their market shares.

Third, R&D expenditures per employee are assumed to reflect the cumulative nature of technological change with a strong impact of the lag of the dependent variable. R&D efforts are sustained by lagged profits that help finance internal innovative activities. Three other aspects of strategy and structure are considered. R&D activities are likely to be higher when industries' innovative behaviour is focused on developing new markets – an additional dimension of the search for technological competitiveness. R&D is expected to be higher in larger firms, testing the relevance of the "Schumpeter Mark II" model of "deepening" technological change.[10] The need to carry out R&D is assumed to be greater when industries have a lower distance from the technology frontier (proxied by productivity levels in the most efficient country).

With this three equation system we move beyond studies – typical of the innovation literature – focusing on one-way relationships in the determinants of R&D, in the links between technological inputs and outputs, and between innovation and performance. Our model adopts a medium-run perspective and integrates demand and supply dynamics; its focus on industries – both manufacturing and services – makes it capable to account for the evolution of the overall economies of advanced countries. Most importantly, our model can be empirically tested, using data for European countries.

[10] See Breschi et al. (2000). The "deepening" pattern is typical of sectors where cumulativeness and barriers to entry - and therefore large firm size - are important; the "widening" pattern reflects the technological trajectories where entry and creative destruction are dominant processes.

3 Data and Methodology

We will estimate the system on data coming from the Sectoral Innovation Database (SID), combining CIS data at industry level with performance data from STAN built by the University of Urbino. It merges most variables of the three comparable waves of the Community Innovation Surveys (CIS 2, 3, 4) and other economic data on performance and employment from OECD-STAN. The unit is the industry: data have been matched at two-digit level for 38 manufacturing and market services, respectively 21 for the former and 17 for the latter. The matching is possible since data from CIS are representative of the overall population of firms, due to proper weighting procedure.

The country coverage of the database includes 8 major European countries – Germany, France, Italy, Norway, Netherlands, Portugal, Spain, and United Kingdom - that represent a large part of the European Economy. The selection of countries and sectors has been made in order to make sure that no confidentiality problems in the access to data emerge (due to the policies on data release by national statistical institutes or to the low number of firms in a given sector of a given country); therefore all available data are certified free from confidentiality problems by the national data provider.

The full description of the sources and methodology followed for the construction of the database is provided in the SID Methodological Notes (University of Urbino, 2007).

With regard to innovation variables, SID includes several dimensions of innovative activities, including R&D expenditures, total innovation expenditures, expenditures for new machinery, external technological acquisitions, patents, innovative turnover, product innovation, process innovation, the sources of information relevant to innovation and its objectives; the funding of innovation; the obstacles to innovation; and the links with business strategies and organisational change. They refer to three time windows, 1994-1996 for the wave two of CIS, 1998-2000 for the third wave and finally 2002-2004 for the fourth one.

In order to investigate at the same sectoral level the crucial links between innovation and several dimensions of economic performance and employment the innovation dataset has been merged by the University of Urbino with an economic performance dataset containing data on economic variables at the same two digit industry level for manufacturing and services. The integration with the economic performance dataset has been carried out using the STAN database (drawn from OECD). Particular care has been adopted for the matching of data from the same two digit industries in the innovation and economic databases, considering the methodological problems and country specificities pointed out by the data providers.

The reference period for the economic performance variable is 1994-2006 for most variables, overlapping with that of the three innovation surveys.

Expenditure variables are deflated using the GDP deflator from EUROSTAT (base year 2002) and for the non-Euro countries we used also a PPP correction (from Stapel et al. 2004). The innovation and economic variables used in this study are listed in Table 1 together with the source.

Table 1. SID Database: Variables used in this study

Variable Description	Unit	Source
Share of firms innovating with the aim to open new	%	CIS

markets		
Share of firms introducing innovative machinery and equipment	%	CIS
Share of turnover from new or improved products	%	CIS
Share of firms defining suppliers of equipment as source of inn.	%	CIS
In House R&D expenditure per employee	Thousands euros/empl	CIS
Compound rate of growth of Value Added	annual rate of growth	STAN
Compound rate of growth of Operating Surplus	annual rate of growth	STAN

In order to use the SID in panel form, we need to test that the sample design or other statistical problems during the gathering of the data in the different waves is not affecting the reliability of data. Besides obvious time-effects capturing macroeconomic dynamics, we would like to manage a stable database. A very detailed empirical investigation has been done by the technical report Bogliacino and Pianta (2009b), to which the interested reader may refer.

3.1. Methodological Issues

In order to estimate the system on the SID database, we will use system Two-Stage-Least-Squares (2SLS from now on), which under mild assumptions allows the identification of the coefficients. It is well known that system 2SLS is equivalent to 2SLS performed equation by equation (Wooldridge, 2002: 192). There is a trade off between consistency and efficiency in choosing an estimator. Due to modest sample size (inevitable with industry level data), we solve the trade-off relying on consistency instead of efficiency. In fact, with 2SLS we only have to care about the orthogonality inside each equation, without taking care of what is happening elsewhere in the system (Wooldridge, 2002: 199). As a result, we can focus on the choice of instruments equation by equation in order to guarantee identification.

In Annex 1 we discuss the identification and all diagnostic tests in detail. Moreover, since the larger temporal dimension is a significant difference from the benchmark literature, we discuss equation by equation the choice of the proper lags.

The time structure deserves a remark. We have to harmonize CIS data, which are referred to on a three-year period, with time lags of four years, with STAN data that are annual. For this reason, we choose to use as reference year for our time index the final year of the CIS wave - to which most of the variables are explicitly referred to in CIS survey- thus considering time lags of four years (1996, 2000, 2004). We input CIS data to the final year of each wave, and we take from STAN the corresponding values. However, to see the effect of the technological effort of 2004 we need to have data of 2008, but STAN is not updated to that year.

We proceed in the following way: All estimations are made on data on first (log-) difference in order to control for unobserved heterogeneity. Since data up to 2008 are not available, we will look for a transformation of first difference, which is not affecting the basic assumptions on the random errors and makes estimation possible with available data. If we divide for the time span of each temporal window, we are simply making a linear transformation, which does not alter the assumptions over the disturbance term. Practically we are replacing long run rate of change with average annual rate of change. In this way we can stop at 2006 (the last year available). Proceeding in this way, we directly calculate the average rate of change over 1996-1999 to cover the first time span; 2000-2003 for the second; and 2003-2006 for the third (the small readjustment of the time windows, i.e. instead of using 1996-2000, 2000-2004, 2004-2006, is caused by the need to have a sufficiently long time span).

4 Results

The results of our estimates are shown separately for each equation in the three tables below. We run the estimation on the overall sample of all manufacturing and service industries, and also on the sub-sample of manufacturing industries alone, which allows comparison with the literature - such as the cited Crepon et al. (1998) and Parisi et al. (2006) - that does not investigate services.

Table 2. The profits equation
Dependent Variable: compound rate of growth of operating surplus.
WLS with robust standard errors and weighted data (weights are the numbers of employee).
t-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) Overall Sample	(2) Manufacturing
Rate of change of value added	1.15	1.08
	[6.33]***	[4.78]***
Difference in Inn. Turnover (first lag)	0.11	0.17
	[1.88]*	[1.97]*
Constant	-3.21	-3.11
	[4.35]***	[-3.05]***
N.observations	232	191
R2	0.24	0.27

Table 3. The Innovation Performance equation
Dependent Variable: Share of innovative turnover.
2SLS with robust standard errors and weighted data (weights are the numbers of employee).
Included Endogenous: R&D expenditure
Excluded Instruments: first lag of R&D, country dummies, a time trend, a lag for demand growth, share of firms aiming to open up a new market and average size of firm.
z-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) Overall Sample	(2) Manufacturing
R&D expenditure per employee	2.20	1.96
	[3.27]***	[2.98]***
Technology adoption	0.13	0.07
	[2.62]***	[1.21]
Rate of change of value added	0.11	-0.72
	[0.61]	[2.88] ***
Constant	8.20	9.32
	[7.09]***	[5.86]***
N obs	145	100
Uncentered R2	0.74	0.78
Overidentification Test (Hansen J statistic)	14.19	20.74
p-value	0.07	0.00

First Stage Diagnostics		
Model F-Test (R&D)	5.80	5.56
p-value	0.0000	0.0000

Table 4. The R&D equation
Dependent Variable: R&D expenditure per employee.
2SLS with robust standard errors and weighted data (weights are the numbers of employee).
Included Endogenous: R&D expenditure (first lag) and Opportunity (percentage distance of the labour productivity level from the leader industry in Europe)
Excluded Instruments: first lag of R&D, country dummies, demand growth, lag of SSUP.
z-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1) Overall Sample	(2) Manufacturing
R&D expenditure per employee (first lag)	0.92 [7.97]***	0.79 [6.73]***
Rate of growth of profits (first lag)	0.05 [1.87]*	0.06 [1.92]*
Size	-0.00 [-0.70]	0.01 [1.91]*
Opportunity	-0.01 [-2.71]***	-0.05 [-2.57]**
New market objective	-0.00 [-0.03]	-0.04 [-1.51]
Constant	0.78 [1.79]*	1.95 [2.17]**
N obs	301	134
Uncentered R2	0.68	0.72
Overidentification Test (Hansen J statistic)	10.17	12.96
p-value	0.25	0.11
First Stage Diagnostics		
Model F-Test (OPP)	38.86	18.67
p-value	0.0000	0.0000
Model F-Test (R&D first lag)	3.51	19.62
p-value	0.0002	0.0000

The results are consistent without framework. Diagnostic test, lag structure and robustness are discussed in detail in Annex 1.

The results of Table 2 show that the change in profits is explained by the effect of growing value added (a proxy of demand) and the introduction of successful innovations (reflecting the evolution of technological competences, supply structures and market power). As expected, while demand acts contemporaneously, technology acts through a lag. This is coherent with the Schumpeterian assumptions that innovation is a trial-and-error and time consuming process. The results for manufacturing industries alone are close to those on the overall sample.

As shown in Table 3 for the innovative performance equation, both technological competitiveness (associated to R&D) and cost competitiveness (associated to technology

adoption from external suppliers) strategies positively contribute to the innovative turnover. Demand growth (proxied by value added) turns out to be non significant. One possible explanation is the existence of the contrasting effects, either "pulling" a higher innovative turnover, or allowing for higher sales with no need for innovation (for instance where strong market power exists). In this case, there are some differences between manufacturing and services. In the case of manufacturing industries demand is negative and significant; moreover, technology adoption loses its significance, as the simple reliance on suppliers can be inadequate for achieving a greater innovative turnover; in manufacturing the dominant effect of technology adoption (of new machinery in particular) has rather been the reduction of labour use associated to widespread processes of restructuring (see Bogliacino and Pianta 2010).

The results of Table 4 highlight three important results in the R&D equation. First, we confirm empirically the feedback effect of economic performance on R&D, since the lag of profits is significant both in overall sample and manufacturing. Second, we confirm the path-dependent nature of technological competitiveness and R&D activities; in fact we find a strong first lag effect for R&D efforts. Third, the pressure for carrying out R&D is stronger the closer the industry is to the technological frontier: i.e. the variable on opportunity is negative and significant. All three results are found for both the overall sample and for manufacturing alone. The effect of firm size on R&D is not significant for the overall sample and is modestly relevant for manufacturing. The aim to develop new markets is never significant.

Our findings show that the growth of industries' profits is jointly driven by the "pull" effect of expanding demand and value added, and by the "push" effect of the success of lagged innovation performance. They, in turn, are supported by the parallel efforts searching for technological competitiveness - through R&D - and for cost competitiveness - through the adoption of new technologies (embodied in new machinery and intermediate inputs) from a range of external suppliers. While both strategies can be pursued in parallel, industries are characterised by a dominance of either pattern of competitiveness; therefore, an explicit consideration of both mechanisms is needed in order to explain innovation performance across industries. R&D activities are cumulative and path-dependent; they are supported by lagged profits; they are higher when industries are closer to the technological frontier; and the evolution of European manufacturing and service industries suggests that the traditional expectation of a link between firm size and R&D is rejected.

Finally, our analysis provides a thorough analysis of the lag structure of the key relationships. This is an important issue, considering the time required by learning processes, R&D efforts, and technological activities before they emerge with an impact in markets and economic performance. It is an issue that has rarely been addressed, due to the focus of previous studies on cross-sectional investigations of innovation survey data. By using our SID database, covering three waves of the CIS, we have been able to document the presence of lagged effects, and to assess their length. The key lags identified include the influence of lagged profits on R&D efforts, the cumulative effects of past R&D on current one, and the effect of lagged innovative turnover on profits.

5 Conclusions & implications for policy

This paper investigates the long term relationship between innovation and performance. We first propose a conceptual approach in the spirit of Crepon et al. (1998) and Parisi et al. (2006), developed into a model that can simultaneously explain, in a three equation system, the determinants of R&D, innovative performance and profit growth in manufacturing and service industries in eight major European countries.

Our main findings can be summarized as follows:

(a) Sectoral specificities are very important and more important than country effects. As a result, disaggregated studies, either at meso level or at micro level are more important when technological change is discussed;

(b) The distinction between technological competitiveness and cost competitiveness is confirmed: although they may coexist in the same industry, their consequences are clearly different, as a sizable literature has already documented, especially with regards to the labour market implications;

(c) With regards to the model, we have some key empirical evidence of our hypothesis. R&D per employee is path dependent, and it is positively affected by the lagged growth of profits and negatively by the distance from the technological frontier in the industry. The share of innovative turnover is positively affected by both technological competitiveness and cost competitiveness. The profitability is explained by the relevance of lagged innovative sales, and by the growth of demand;

(d) There is a clear lag between factors influencing knowledge, technological activities and economic performance. We have explored in detail the lag structure of the structural relationship and we have found a significant influence of lagged profits on R&D efforts, of the cumulative effects of past R&D on current one, and the effect of lagged innovative turnover on profits. We have tested the relevance of lags of different duration, finding that the three to four year lag is the most relevant one;

(e) The results for manufacturing and services and those for manufacturing industries alone have limited differences. This represents further evidence that the distinction between manufacturing and services is obsolete when we look at innovation dynamics. Other conceptualization, such as Pavitt taxonomy or high-tech/medium-tech/low-tech can be more promising avenues to be explored.

Some clear policy considerations emerge from our results:

(a) Demand side factors have a significant influence on innovative and economic performance; while policies in European countries have traditionally focused on supply-side actions, greater support for industry-level demand could be an effective tool for improving innovation and growth;

(b) The relevance of internal resources suggests that financing of R&D is indeed an issue, which should be addressed either through the development of a venture capital market, or through specific policies;

(c) The lags that we have identified mean that implementation of policies supporting R&D and innovation need time to display their effects. R&D and innovation policies are long-term instruments and should be designed, monitored and implemented with a long-term perspective;

(d) The relevance of the distance from the frontier in negatively affecting R&D may be an indication that technological capabilities are very important. As a result, education policies and other instruments supporting human capital and knowledge accumulation are likely to be complementary to R&D policies.

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Annex

Annex 1. Diagnostic Tests

In this Annex we discuss the technical problems of identification and diagnostic test. We will proceed equation by equation. Moreover, given the importance of establishing a temporal structure, we discuss the optimal lag for the regressors.

With regards to the profit equation, as you can see in the following Table, there is: a Breusch-Pagan test for heteroschedasticity (which is not rejected), a Variance Inflating Factors analysis for multicollinearity, and an exogeneity test[11]. The results do not reject our formulation, and we have to estimate robust standard errors (the Breusch-Pagan rejected the null hypothesis of homoschedasticity), explanatory variables are orthogonal to the error term, and multicollinearity is not an issue. We can maintain a WLS with robust standard errors.

Table A1. Profits equation

Breusch-Pagan Test	
Chi2(1)	11.04
p-value	0.0009
Multicollinearity	
Average Variance Inflating Factor	1.02
Exogeneity	
t-statistics (Delta-Inn.Turnover)	-0.16
p-value	0.87
t-statistics (Rate of change of VA)	-0.56
p-value	0.57

We can now try to define the optimal lag for the first equation. We run the baseline formulation with the explanatory variables up to the second lag. As one can see from the following Table,

[11] We regress the explanatory variables over a set of instruments (lagged rate of change of value added, country dummies, time dummies, average size of firms, share of firms aiming to open up new markets), compute the residuals and re-run a robust standard errors-WLS of (3) with the residuals included. The T-test for the coefficient of the residuals included becomes a test of endogeneity, see Wooldridge (2002, p. 118). The country dummies are included since they impact also on the growth pattern and not only on the level of turnover and thus we do not get rid of them through first differencing. We carried out also a test for persistence, but the lag of the dependent variable is not significant.

it is only the contemporaneous period for demand and the first lag for innovative performance that have explanatory power in the equation.

Table A2. The lag structure of the profits equation
Dependent Variable: compound rate of growth of operating surplus.
WLS with robust standard errors and weighted data (weights are the numbers of employee).
t-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1)	(2)
Rate of change of value added	1.15	1.50
	[6.17]***	[6.63]***
Rate of change of value added (first lag)	-0.02	
	[0.84]	
Difference in Inn. Turnover (first lag)	0.11	0.45
	[1.83]*	[2.72]***
Difference in Inn. Turnover (second lag)		0.31
		[1.24]
Constant	-3.19	-0.96
	[4.23] ***	[-0.46]
N.observations	230	74
R2	0.24	0.27

The empirical evidence does not reject our formulation. The proper lag is clearly the significant one, thus we maintain the structure as in (3).

Turning the attention to the second equation, we have to discuss the identification strategy, passing through the same steps as above. However, we know from theoretical reasoning (and data confirm it) that R&D expenditure is endogenous. In fact it is autoregressive and path dependent. Innovative capabilities are related to past and present R&D effort, and therefore we instrument it with its first lag, country dummies, a time trend, demand growth, a lag for demand growth, share of firms indicating suppliers as source of innovation, share of firms aiming to open up a new market and average size of firm. For this reason, we test exogeneity of *SSUP* and demand growth only (the companion regression for the test is now a 2SLS with robust standard error and weighted data).

Table A3. The Innovation Performance equation

Breusch-Pagan Test	
Chi2(1)	171.50
p-value	0.0000
Multicollinearity	
Average Variance Inflating Factor	1.02
Exogeneity	
t-statistics (SSUP)	-0.08
p-value	0.94
t-statistics (Rate of change of VA)	-1.91
p-value	0.06

Exogeneity is not rejected at the five percent level. We maintain a 2SLS formulation with the above instruments, robust standard errors and weighted data.

We can now consider the lag structure. Demand is relevant only when considered contemporaneously (there are no robust reasons to expect that past demand should matter for today's innovative turnover).

The results from the table below show that instruments behave properly. Our lag formulation is satisfied with regard to R&D (the first lag is not significant). There is a variance inflation problem when we use both *SSUP* and its first lag (the two become not significant); we cannot distinguish the two on the basis of empirical evidence. However, using the contemporaneous measure (given that identification tests are positive) allows taking into account all adoption of technology and appears theoretically stronger.

Table A4. The Innovation Performance equation
Dependent Variable: Share of innovative turnover.
2SLS with robust standard errors and weighted data (weights are the numbers of employee).
Included Endogenous: R&D expenditure
Excluded Instruments: first lag of R&D, country dummies, a time trend, a lag for demand growth, share of firms aiming to open up a new market and average size of firm.
z-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1)	(2)
R&D expenditure per employee	4.55	1.88
	[3.32]***	[2.98]***
R&D expenditure per employee (first lag)	-1.71	
	[-1.31]	
Technology adoption	0.14	0.089
	[1.92]*	[1.65]
Technology adoption (first lag)		0.13
		[1.44]
Rate of change of value added	0.07	0.10
	[0.33]	[0.53]
Constant	6.94	6.02
	[5.09]***	[3.24]***
N. obs.	145	144
Uncentered R2	0.47	0.72
Overidentification Test (Hansen J statistic)	10.65	15.42
p-value	0.15	0.05

Finally for the R&D equation, our battery of tests for the identification is presented in the Table below. For the exogeneity test, the companion estimation is a weighted 2SLS with robust standard errors, with included endogenous and excluded instruments discussed above. We limit the exogeneity test to the size variable (profits are lagged and *EMAR* conceptually cannot be endogenous).

Table A5. The R&D equation

Breusch-Pagan Test	
Chi2(1)	972.20
p-value	0.0000
Multicollinearity	
Average Variance Inflating Factor	1.12
Exogeneity	
t-statistics (SIZE)	-0.06
p-value	0.52

With regard to the lag structure we are interested in the transmission of internal resources to the R&D decision. We thus estimated an equation with two lags of the rate of growth of profits and look at the z-statistics for both.

Table A6. The R&D equation.
Dependent Variable: R&D expenditure per employee.
2SLS with robust standard errors and weighted data (weights are the numbers of employee).
Included Endogenous: R&D expenditure (first lag) and Opportunity (percentage distance of the labour productivity level from the leader industry in Europe)
Excluded Instruments: first lag of R&D, country dummies, demand growth, lag of SSUP.
z-stat in brackets.
* significant at 10%, ** significant at 5%, *** significant at 1%.

	(1)
R&D expenditure per employee (first lag)	0.92 [7.97]***
Rate of growth of profits (first lag)	0.06 [2.41]**
Rate of growth of profits (second lag)	0.00 [0.21]
Size	-0.00 [-2.20]**
Opportunity	-0.02 [-2.73]***
New market objective	-0.01 [-0.76]
Constant	1.31 [2.87]***
N obs	186
Uncentered R2	0.58
Overidentification Test (Hansen J statistic)	19.00
p-value	0.01

The basic formulation is not rejected by data. On the basis of this evidence, in the lag structure of the model we opt for the first lag for R&D and profits.

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European Commission
EUR 24325 EN/5 – Joint Research Centre – Institute for Prospective Technological Studies
IPTS WORKING PAPER on CORPORATE R&D AND INNOVATION - No. 05/2010
Title: Profits, R&D and Innovation: a Model and a Test
Author(s): Francesco Bogliacino (European Commission, Joint Research Center- Institute for Prospective Technological Studies, Sevilla; Centro de Estudios Para America Latina y el Caribe-Universidad EAFIT, Rise Group, Medellin) and Mario Pianta (University of Urbino and Lunaria).
Luxembourg: Office for Official Publications of the European Communities
2010
EUR – Scientific and Technical Research series – ISSN 1018-5593
Technical Note – ISSN 1831-872X
ISBN 978-92-79-16242-8
doi:10.2791/44497

Abstract

In this article we investigate – both conceptually and empirically – the relationship between three interconnected elements of the Schumpeterian "engine of progress": the ability of industries' R&D efforts to turn out successful innovations; the ability of innovations to lead to high entrepreneurial profits; the commitment of industries to invest profits in further technological efforts. We build a simultaneous three-equation model – with appropriate lags – and we test it at industry level – for 38 manufacturing and service sectors – on eight European countries over two time periods from 1994 to 2006. The results show that the model effectively accounts for the dynamics of European industries.

Our main results are that demand and innovation are the key determinants for firm profitability; second that both technology adoption and R&D concur to improve innovative performance; third, that R&D is path dependent and is negatively related to the distance from the frontier. Finally, manufacturing and services show similar behaviour.

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LF-ND-24325-EN-C