Innovation and Demand in Industry Dynamics: R&D, New Products and Profits

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Abstract The links between three interconnected elements of the Schumpeterian sources of economic change are explored, conceptually and empirically, and related to the role played by demand factors. First, we examine the commitment of industries to invest profits in cumulative R&D efforts; second, the ability of industries' R&D to introduce to new products in markets; third, the impact of new products on entrepreneurial profits. We consider the nature and variety of innovative efforts—distinguishing in particular between strategies of technological and cost competiveness—and we introduce the role of demand in pulling technological change and supporting profits. We develop a simultaneous three-equation model and we test it at industry level—for 38 manufacturing and service sectors—on six European countries over two time periods from 1994 to 2006. The results show that the model effectively accounts for the dynamics of European industries and highlights the interconnections between the different factors contributing to growth.

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1 Introduction[1]

Economic change in advanced countries can be seen—in a Schumpeterian perspective—as the result of three processes that are closely interconnected. First, the cumulative nature of knowledge and R&D, supported by *technology push* and *demand pull* factors, and by the commitment of firms and industries to invest profits in research activities. Second, the ability of industries' R&D to lead to successful innovations, combining developments on the supply and the demand side. Third, the impact of new products, new processes, and demand growth on entrepreneurial profits.

This article explores these complex relationships and investigates the links between innovation and economic performance in an integrated perspective. Much economic research has investigated these issues either considering externalities and spillovers as major channels for the diffusion of knowledge and technologies (Griliches 1979, 1992, 1995; Griffith et al. 2004), or focusing on R&D driven technological change that leads to endogenous growth (see Aghion and Howitt 1998 for a general discussion of the literature). We aim to enlarge the picture, considering the *diversity* of innovative efforts—that include not just R&D, but also innovative investment, adoption of new technologies, learning processes, etc. -, the *uncertainty* of technological change—addressing innovative *outputs* as well as *inputs*, such as R&D—and the *feedback* effects that may exists among the different relationships.

A few contributions have explored the links between innovation and economic performance by breaking down this sequence of relationships and estimating empirically different phases: the decision to invest in R&D, the relationship between inputs ad outputs and the effect of R&D on economic performance (Crepon et al. 1998; Parisi et al. 2006). In a recent work (Bogliacino and Pianta 2012) we develop a model with a three-equation system that explains R&D intensities, the importance of innovative in sales and the growth of profits; an empirical test is carried out at the industry level for major European countries. We find that R&D supports successful innovations and that they lead to higher profits, which in turn finance R&D, with a complex structure of lags and feedbacks.

In this chapter we build on that approach and provide two main novelties. First, we integrate the analysis of the innovation-performance link with the demand side, exploring the role of different demand factors—exports, domestic consumption, intermediate demand, etc.—in the equations. Second, we consider the determinants of product innovations, that reflect a strategy of *technological competitiveness*, and

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we investigate in parallel the impact of process innovations and acquisition of new machinery, associated to a search for *cost competitiveness*.

The role of demand has often been neglected in neo-Schumpeterian approaches (see the discussion in Crespi and Pianta 2007, 2008a, b); while the importance of new markets and demand pull effects in stimulating innovation is usually acknowledged, few studies have empirically examined the specific sources of demand that affect innovation. A major contribution of this chapter is the integration in our model of different demand variables, using information drawn from Input–output tables—based on the work on structural change in European industries by Lucchese (2011). By considering the evidence on demand dynamics we can reliably test the importance of different demand sources in the emergence of new products and in the dynamics of profits.

The chapter proceeds as follows. Section 2 presents the model; Sect. 3 data and methodology, Sect. 4 the results and Sect. 5 the concluding remarks.

2 The Model: Linking R&D, New Products and Profits

We estimate a system of equations that account for R&D efforts, product innovation and profits growth. In the following subsections we put forth the theoretical basis of each part of analysis and we discuss the points of contact with the existing literature.

2.1 The Decision to Carry Out R&D Efforts

We follow evolutionary approaches to R&D efforts in firms and industries. R&D is a path dependent process because the paradigm (and trajectory) related development of technology makes the process of search eminently localized (Atkinson and Stiglitz 1969; Nelson and Winter 1982; Dosi 1982, 1988). R&D is affected by demand pull (Schmookler 1966; Scherer 1982) and technology push effects (Mowery and Rosenberg 1979). According to the former perspective, innovation is brought to the market when firms anticipate strong demand; in the latter view innovation is supported by science-related developments and is triggered by relative prices in a feasible production set. Moreover, innovation is persistently characterized by the presence of specific technological and production capabilities (Pavitt 1984; Dosi 1988; Malerba 2004; Metcalfe 2010).

R&D may be cash constrained (Hall 2002), due to the intangible nature of R&D which is difficult to collateralize and due to informational problems, namely the “radically uncertain” nature of research and the asymmetric distribution of information in the classical lender–borrower case (Stiglitz and Weiss 1981). Under these conditions, profits from past innovation play a major role in financing R&D. Our first equation is the following:

$$R\&D_{ijt} = \alpha_0 + \alpha_1 R\&D_{ijt-1} + \alpha_2 DP_{ijt} + \alpha_3 FR_{ijt} + \alpha_4 \pi_{ijt-1} + \varepsilon_{ijt} \quad (1)$$

where, from now on, i indicates industry, j country, t time. R&D is research and development (thousands of euros per employee in our data), and is affected by its lag; DP stands for *demand pull* and reflects the potential for the introduction of new products, captured by the objective of opening up new markets reported by innovation surveys, FR is the distance from the capability frontier, calculated as the difference in labour productivity from the industry leader, π represents operating profits (with a one period lag) and the last term is the standard error. In Sect. 3.2 we discuss the proxies used from our database.

The *demand pull* versus *technology push* debate has led to several contributions that have investigated the respective influences on R&D and innovation, and controlled for capabilities. Kleinkecht and Verspagen (1990) find a significant effect of demand after controlling for path dependency. Piva and Vivarelli (2007) estimate demand pull effects for different groups of firms; the effect of demand is higher for firms which export, do not receive public subsidies, are liquidity constrained, diversified, large and in medium and low tech sectors. Bogliacino and Gómez (2010) found a negative and significant effect of the distance from the production frontier, which is a proxy for technological capabilities. A more recent strand of research has used data from innovation surveys (for a review see Mairesse and Mohnen 2010), finding that R&D efforts are positively influenced by size and public support to innovation.

A further strand of literature has tried to detect the effect of firm size on R&D (Cohen and Levine 1989; Cohen 2010). This line of research has been criticized for being unclear on whether it is innovation input or output that is affected by size and for the risk of endogeneity, given that both market structure and innovation are codetermined by the fundamental features of the sector (appropriability, cumulativeness and the knowledge base, see Breschi et al. 2000).

The importance of profits in supporting innovation was pointed out by Schumpeter[2] but has led to a limited literature; studies on financial constraints in R&D investment are reviewed by Cincera and Ravet (2010). In their empirical exercise—using data from the R&D Scoreboard which covers the largest R&D investors—they found that cash constraints are important for EU but not US firms. Their argument is indirectly supported by Brown et al. (2009) who found that the "dot.com bubble" played a major role in allowing R&D expenditure growth in the US in the 1990s. Finally, in the previous version of our model (Bogliacino and Pianta 2012) we find a negative effect of the distance from the frontier—i.e. more R&D is carried out when industries are closer to the capability frontier—and a positive effect of profits from past innovation.

[2] "Whence come the sums needed to purchase the means of production necessary for the new combinations if the individual concerned does not happen to have them? (. . .) By far the greater part (. . .) consists of funds which are themselves the result of successful innovation and in which we shall later recognise entrepreneurial profit" (Schumpeter 1955, 71–72). See also O'Sullivan (2006).

By carrying out our investigation at the industry level—for both manufacturing and services—we are able to consider broad feedbacks between economic performance, innovative efforts and demand dynamics.

Studies at the firm level have focused on the role of profits as sources of finance for cash constrained R&D, have provided controversial evidence on the ability of higher profits to support greater R&D[3] and—according to the performance feedback theory (Greeve 2003)—have argued that firms with profits below expected targets could increase R&D and adjust their organizational routines in order to meet their objectives. On the other hand, when we move to the industry level of analysis, the positive association between past profits and R&D is more straightforward as the overall R&D efforts of a sector can be driven by past profits of incumbent firms that attract entry by new innovative firms. The performance feedback is also taken into account by the relationships at the industry level; firms can define their target profits in relation to industry averages; when they operate in high profit sectors their increase in R&D efforts can contribute to the overall high levels of R&D; when they operate in low profit industries, expectations will be lowered, driving down R&D efforts.

Studies at the firm level consider a perfectly elastic demand for individual firms and therefore do not consider the presence of demand constraints. At the industry level, on the other hand, the dynamics of demand is constrained—it is defined by the distribution across industries of the growth of aggregate demand—and a consideration of the different sources of demand becomes important (for a discussion, see Bogliacino and Pianta 2012).

2.2 Explaining Product Innovation

Economic change is shaped by successful innovations, rather than by R&D inputs. For this reason several models—such as Crepon et al. (1998), Parisi et al. (2006) and Bogliacino and Pianta (2012)—add a second equation on the relationship between innovation inputs and outputs. The conceptualisation of innovation is important in this context; a large evolutionary literature has pointed out the role of different modes of innovation depending on the technological trajectory associated with each sector (Pavitt 1984; Dosi 1988; Malerba 2002, 2004 among the others). Pianta (2001) suggested to return to the original Schumpeterian distinction between product and process innovation; although they often are complementary, they are usually associated with different objectives and generate different effects in terms of growth, employment and distribution (see Crespi and Pianta 2007, 2008a, b; Pianta and Tancioni 2008; Bogliacino and Pianta 2010, 2012) and should be kept analytically distinct. As a result Pianta (2001) proposed the concepts

[3] Among several studies, Bogliacino and Gómez (2010) found a positive link between profits and R&D, while Coad and Rao (2010) found a weak association.

of *technological* and *cost competitiveness* to summarise on the one hand innovation strategies focusing on new markets, new products and R&D, as opposed to efforts directed at labour saving new machinery, efficiency gains and cost reductions.

Technological competitiveness is explained in our second equation by R&D efforts, demand dynamics and market structure.[4] Conversely, efforts for cost competitiveness and process innovation—measured by the adoption of new machinery and equipment—have an effect on economic performance; and are included in the profit equation [(3) below].

Our second equation is the following:

$$TC_{ijt} = \beta_0 + \beta_1 R\&D_{ijt-1} + \beta_2 D_{ijt} + \beta_3 MS_{ijt} + \varepsilon_{it} \tag{2}$$

where TC stands for technological competitiveness—proxied by the share of firms that are product innovators in each industry -, R&D is the variable estimated by (1) with one lag, D stands for one or more variables on the rates of growth of demand directed to the industry, and MS is a measure of market structure, namely average firm size in the industry.

Successful innovation leading to new products and new markets requires R&D inputs and—as in the Schumpeterian "mark II" models—is often characterised by the presence of large firms with strong capabilities for exploiting knowledge, and oligopolistic market structures, where high incentives to generate product innovations exists. Finally, demand may play a role in several ways. The *demand pull* perspective and the literature on structural change (Pasinetti 1981) emphasises the positive effect that a strong demand dynamics has on the development and diffusion of new products. This is a complementary approach to the Schumpeterian analysis of the way major innovations change the economy. However, when an economy—or an industry—operates in the Schumpeterian "circular flow", without major innovations, current demand for standard products may reduce the incentive to develop new products and delay their introduction. Therefore, demand that matches relevant technological change—the most dynamics components of demand, such as exports—is likely to support the introduction of new products in a virtuous circle between capabilities, innovations and markets (as in the "learning by exporting" hypothesis, see Crespi et al. 2008). Conversely, demand that is related to the activity of industries where a "circular flow" prevails—such as demand for consumption and for intermediate goods—may lead to less incentives for the introduction of new products.

[4] Some studies have tried to explore the relationships of (2) using patents as a measure of product innovation; a review can be found in Denicolò (2007). However, a large literature has shown that patents are a biased indicator and capture very poorly the innovation output outside Science Based industries (for a discussion on measuring innovation, see Archibugi and Pianta 1996; Smith 2005).

2.3 Explaining the Dynamics of Profits

Following Bogliacino and Pianta (2012), we add a third equation for the dynamics of profits. We depart from previous work such as Crepon et al. (1998) and Parisi et al. (2006), where the performance equation explains productivity growth. These contributions use productivity because, at the firm level and with a short time dimension, any measure of profits is likely to be highly volatile. Our use of industry level data and our time structure (broader, and based on long differences as discussed below) allows using stable indicators of profit growth as the most appropriate measure of industry performance.

In our formulation, profits are affected by technological and market factors. On the one hand profits are supported by successful efforts to achieve both technological and cost competitiveness; the former is the variable—importance of product innovation—resulting from (2); the latter is the relevance of technology adoption and investment in new machinery. On the other hand, strong market demand for industries' output is reflected in growth of production and sales. Our third equation of the system is the following:

$$\pi_{ijt} = \gamma_0 + \gamma_1 TC_{ijt} + \gamma_2 CC_{ijt} + \gamma_3 PR_{ijt} + \varepsilon_{ijt} \tag{3}$$

where π is the growth of profits—proxied by data on industries' operating surplus—TC and CC are technological and cost competitiveness as defined above; the former is the predicted value from (2), the latter is proxied by expenditure in new machinery (thousand of euros per employee); finally PR stands for growth of total production—proxied by growth of industry sales—that reflects overall industry demand.

The literature on the determinants of profits and on the impact of innovation is not very large (Teece 1986; Geroski et al. 1993; Cefis and Ciccarelli 2005; Pianta and Tancioni 2008; Bogliacino and Pianta 2012) and has generally found a significant effect of all types of innovation on profits.

3 Data and Methodology

3.1 Data

In the empirical analysis we use industry level data from the Urbino Sectoral Database (USD) developed at the University of Urbino (Pianta et al. 2012) that includes data from three European Community Innovation Surveys—CIS 2 (1994–1996), CIS 3 (1998–2000) and CIS 4 (2002–2004)—matched with data from OECD-STAN for production (that we use as a proxy for sales), value added, employment and operating surplus and data from OECD Input–output tables to calculate demand components. Data are available for the two-digit NACE

Table 1 List of variables from the USD database

Variables	Unit	Source
In-house R&D expenditure per employee	Thousands euros/ empl	CIS
New Machinery expenditure per employee	Thousands euros/ empl	CIS
Share of product innovators	%	CIS
Share of firms innovating with the aim to open new markets	%	CIS
Average firm size	Number empl per firm	CIS
Compound rate of growth of export	Annual rate of growth	OECD I-O Tab.
Compound rate of growth of intermediate demand	Annual rate of growth	OECD I-O Tab.
Compound rate of growth of household final demand	Annual rate of growth	OECD I-O Tab.
Distance in labour productivity from the frontier	%	Elab. on STAN
Compound rate of growth of production	Annual rate of growth	STAN
Compound rate of growth of operating surplus	Annual rate of growth	STAN

classification for 21 manufacturing and 17 service sectors; all data refer to the total activities of industries.[5]

The country coverage of the database includes six major European countries—Germany, France, Italy, Netherlands, 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 avoid limitations in access to data (due to the low number of firms in a given sector of a given country, or to the policies on data released by national statistical institutes).

Time periods are the following. Economic and demand variables are calculated for the periods 1995–2000 and 2000–2005. Innovation variables refer to 1994–1996 [used for the lagged R&D variable in (1) and (2)]; 1998–2000 (linked to the first period of economic variables); 2002–2004 (linked to the second period of economic variables). The variables used are listed in Table 1.

In order to use these data in panel form, we need to test that the sample design or other statistical problems in the gathering of data are not affecting the reliability of data. Besides considering the time-effects capturing macroeconomic dynamics, we have examined the stability of the database. A very detailed empirical investigation on the characteristics of the database has been carried out (see Bogliacino and Pianta 2012) and we report in the following table the main descriptive statistics (Table 2):

[5] CIS data are representative of the total population of firms and are calculated by national statistical institutes and Eurostat through an appropriate weighting procedure. Economic variables are deflated using the GDP deflator from Eurostat (base year 2002) corrected for PPP (using the index provided in Stapel et al. 2004).

Table 2 Descriptive statistics

Variables	Mean	SD overall	SD between	SD within
In-house R&D expenditure per employee	2.66	4.89	4.10	2.06
New machinery expenditure per employee	1.78	2.68	2.31	1.74
Share of product innovators	36.66	20.36	18.98	9.18
Share of firms innovating with the aim to open new markets	32.14	20.04	16.80	11.57
Average firm size	223.72	455.35	357.10	278.42
Compound rate of growth of export	6.39	16.81	11.09	12.64
Compound rate of growth of intermediate demand	3.01	7.20	5.10	5.09
Compound rate of growth of household final demand	2.64	10.67	6.64	8.49
Distance in labour productivity from the frontier	29.84	22.14	20.57	8.27
Compound rate of growth of production	2.92	5.51	4.15	3.71
Compound rate of growth of operating surplus	2.57	15.43	15.57	8.62

3.2 Methodological Issues

We address the problem of endogeneity in three ways. First of all, we estimate the model by Three Stages Least Squares (3SLS) in order to explicitly model the endogenous variables and to control for simultaneity. Secondly, we use the time structure; we introduce lags whenever we have a suspect of endogeneity. Since our time lags are of 3–4 years, the autoregressive character (and the implied endogeneity) is considerably softened. Third, our use of average growth rates is equivalent to the use of long (log) differences which is a standard way in the literature to address the problem of endogeneity (see Caroli and Van Reenen 2001; Piva et al. 2005), besides removing individual time invariant effects. Finally the variables that are not expressed as rates of growth are scaled by the number of employees or firms (the ones expressed as shares), so we are correcting for the potential bias deriving from using groups of unequal size.

Our specification of the model is based on the choice of the following variables.

The R&D equation. The lag of R&D per employee accounts for path dependence and cumulativeness of knowledge. Technology push effects are likely to be internal to the sector, or controlled for by the autoregressive nature of R&D. As a proxy for *demand pull* effects we use the share of firms which innovate to expand the range of products, reflecting expectations on the presence of strong demand for new and improved goods and services.[6] As a proxy for capabilities we use the distance in

[6] We use a variable of objective and not a direct measure of demand for two reasons: first, given the time lag necessary to obtain results from R&D, putting a contemporaneous term would be meaningless; second, the inclusion of a future term would be seriously affected by endogeneity problems and would have implied some form of rational expectations which are unrealistic in a radical uncertainty domain.

percentage points from the labour productivity of the industry in the country where the productivity is the highest.[7] Closeness to the frontier indicates accumulated capabilities and a greater need to carry out R&D as the opportunities for imitating leaders are modest; in this case a negative relationship is therefore expected. Finally, the rate of change of lagged profits is proxied by the operating surplus and is expected to support higher R&D.

The product innovation equation. In order to explain the relevance of technological competitiveness, as dependent variable we use the share of firms that have introduced a product innovation (with or without the parallel introduction of new processes). Lagged R&D per employee has been defined above. The structure and dynamics of demand is measured as the change in demand for goods produced by the industry (calculated from input–output tables), and is accounted for by different variables: the most dynamic component of demand is the rate of change of export, that is expected to have a positive impact on the new products introduced by industries; the rate of change of household final demand and the rate of change of change of intermediate demand for the industry's output may be associated to standard products and may delay the introduction of new ones. Finally, as a measure of market structure we use the average size of firms in the industry.

The profit equation. The share of product innovators in the industry, defined above, is again the proxy we use for accounting for technological competitiveness. The innovation-related expenditure for new machinery per employee is the proxy we use for cost competitiveness. In order to account for the market dynamics of industries we use the rate of growth of production, reflected in industry sales.

4 Results

In the OLS estimation we do not find any particular diagnostic problem, in particular multicollinearity is not an issue: computing the variance inflation factors we found 1.06 for the first equation, 1.14 for the second and 1.21 for the third one. We therefore estimate the system with 3SLS as explained above.

The results of our three equation model are reported in Table 3.

[7] See Bogliacino and Pianta (2012) for a discussion of this variable. For every observation (sector-country) we calculate the labour productivity (value added per employee) in the initial year of the sub-period. Then for each industry we individuate the leader (e.g. for sector x1 the highest labour productivity is in country y2) and we compute the distance in percentage points. At the industry level this variable may be affected by the pattern of countries' competitive advantages; unfortunately with our dataset it is the only available measure.

Table 3 The results of the system: the relationships between R&D, new products and profits three stage least squares

	(1) R&D per employee	(2) Share of product innovators	(3) Rate of growth of profits
R&D per employee (first lag)	0.53 [0.06]***	2.71 [0.28]***	
Rate of growth of profits	0.19 [0.04]**		
New market objective	0.06 [0.02]***		
Distance from the frontier	−0.00 [0.01]		
Size		8.95 [5.38]*	
Rate of growth of export		0.40 [0.16]**	
Rate of growth of final consumption		−0.23 [0.09]***	
Rate of growth of intermediate demand		−0.59 [0.17]***	
Share of product innovators			0.35 [0.09]***
New machinery per employee			0.72 [0.38]*
Rate of growth of production			0.51 [0.19]**
Constant	−0.92 [1.49]	24.80 [1.42]***	−12.71 [3.19]***
Obs	204z	204	201
RMSE	5.30	15.36	17.71
Chi-2 (*p*-value)	198.91 (0.00)	127.90 (0.00)	35.36 (0.00)

S.e. in brackets
Source: USD
*significant at 10 %, **significant at 5 %, ***significant at 1 %

In the R&D equation past R&D and past profits support R&D efforts that are pulled by the presence of a potential market for new products; the distance from the frontier of labour productivity is not significant.

In the product innovation equation, past R&D and firm size have a positive and significant impact, confirming the assumptions of the "Schumpeter mark II" perspective. Demand variables have, as expected, different effects on new products. Export growth is associated to a higher presence of product innovators, in line with the "learning by exporting" hypothesis (Crespi et al. 2008); a high growth of household consumption and intermediate demand, conversely, is associated to lower product innovation; an increase in such components of demand may lower the need to introduce new products, a relationship that is typical of "traditional" industries and services with little R&D, more standard goods and less international openness.[8]

In the third equation profits are pushed in parallel by innovation-driven gains in technological and cost competitiveness, and are pulled by demand-led growth in sales.

The estimated coefficients come out as expected, and the results are consistent with those found in the previous version of our model (Bogliacino and Pianta 2012). In Appendix we provide an additional version of the model without the demand variables, further showing the stability of our results.

In order to check the robustness of our estimations, we address three potential problems: (a) size may be important also in explaining the decision to do R&D, (b) our specification may not control adequately for technology push, (c) there may exist omitted institutional factors at country level.

The relation between size and R&D has been addressed by a large literature that, however, did not lead to clear cut results; we ran estimations adding size among the explanatory variables in the R&D equation, but it did not come out significant. This may be a further indication that size is capturing other effects, such as cash constraints, capabilities effects or, simply, endogeneity. As stressed by Dosi et al. (2007) the heterogeneity is such that no robust evidence is found on support of this hypothesis once the proper control variables have been added. This should be kept into account when assessing previous results with CIS data which usually suggest a size-innovation relationship (see the review in Mairesse and Mohnen 2010).

In order to address point (b) we also included time dummies in the R&D equation, but the results are unchanged, and the dummies are not significant. Indeed, the use of long differences, industry level data, average rate of change and autoregressive specification is a satisfactory strategy to account for time varying production possibilities frontier.

Finally, institutional differences are mainly accounted for through national level fixed effect. It is possible to use specific data on institutional factors at the country level, but given the higher level of aggregation it would be impossible to identify the effect, and the t-test will be unreliable (see Moulton 1986). In our estimation, since we are considering rate of changes, we are eliminating the time invariant dimension. In order to test whether institutional frameworks affect rates of change—that is, whether they have a time-trend impact—we ran the estimations with country dummies in all three equations, and the results do not show appreciable changes in the coefficients.[9]

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[8] A systematic analysis of the links between innovative dynamics, demand factors and structural change is in Lucchese (2011).

[9] We remind also that, technically, the effects captured through country dummies cannot be identified; since our unit of analysis is the industry, which are in fixed numbers, the only way to increase the number of observations is by increasing the number of countries. Asymptotically, the number of country effects diverges at the same rate as the sample size, thus we would face an incidental parameter problem. As a result, we do not report these estimations. All three robustness check regressions are available from the authors upon request.

5 Conclusions

Our model and the empirical results we obtain—focusing on the industry level—appear capable to account for important dimensions of the interconnected engines of economic change in a Schumpeterian perspective. Our three equation system links several insights of the evolutionary literature on innovation and supports them with its empirical results.

In explaining R&D intensities, the cumulative nature of research and knowledge, the *demand pull* effect of the potential for new products, and access to finance through the reinvestment of lagged profits play a significant role.

In explaining the importance of product innovation, the same cumulative nature of R&D and firm size are important on the supply side, while demand factors either stimulate the introduction of new products, in the case of strong export growth, or may delay it when consumption and intermediate demand characterise industries' markets.

In explaining the dynamics of profits we find a direct effect of the previous variable—the importance of product innovation, reflecting a strategy of technological competitiveness—in addition to significant effects of gains in cost competitiveness—through process innovations introducing new machinery. Moreover, fast growing sales reflecting demand growth also contribute to higher increases of profits.

Three improvements on the existing literature emerge from our model and findings.

First, we provide a simultaneous explanation of three interconnected sources of change in advanced economies—R&D, new products and profits. We move from one-way relationships to a system that accounts for simultaneous links and feedback effects, developing Schumpeterian insights and providing support for several evolutionary assumptions. In this chapter we expand the model and test developed in Bogliacino and Pianta (2012), extending the approach by introducing demand variables; the results confirm the strength of the model and the relevance of the empirical findings.

Second, our findings confirm the importance of the diversity of innovative efforts—pointed out by evolutionary approaches—and the strength of our previous work on the distinction between technological competitiveness (based on new products) and cost competitiveness (based on new processes) (Pianta 2001).

Third, while much of the evolutionary literature has neglected the role of demand, we integrate—in our industry-level analysis—both technological and demand factors, showing that innovation in products and profits are deeply affected—in a complex way—by demand factors. This extension of the empirical evidence has been possible thanks to the combination in our database—the USD of the University of Urbino—of innovation survey and economic data with information on demand dynamics drawn from input–output tables for both manufacturing and service industries.

In our model we show that the role of demand emerges in different ways. An increase in overall demand, leading to higher production, drives up profits, but may not be relevant for improved innovative performances. In fact, the increase in product innovations is positively associated to export growth alone; industries with a greater international openness and operating in more competitive markets are pushed to improve their technological competitiveness through new products. Conversely, increased demand due to household consumption or to intermediate demand from other industries may, in effect, slow down the introduction of new products; when domestic demand for existing products in less competitive internal markets increases, firms may be under less pressure to innovate their product range and strengthen their technological capabilities; they may just expand output of existing goods and services, easily obtaining increased profits (as shown by the results of the profit equation).

This diversity of outcomes from different components of demand may have relevant policy implications, emphasising the importance of the "virtuous circle" between R&D efforts, innovation in products, technological competitiveness, export growth—that in last decades has been the most dynamics demand component for EU economies—and higher profits obtained from an expansion of output—rather than from a restructuring driven by labour saving new processes; such profits, in turn, can support larger R&D efforts. Our approach is able to model these complex relationships in an integrated way, with appropriate lags and feedback effects, and to test them empirically. This appears as an improvement on current approaches and opens up novel directions for conceptual and empirical work aiming to explain the complex dynamics of economic change in advanced economies.

Appendix

In order to appreciate the relevance of the inclusion of demand variables in our results in Table 3, we report in Table 4 the results of a different estimate that excludes the proxies for demand and considers other variables only. The structure of results is the same as in Table 3.

Table 4 The system: baseline formulation three stage least squares

	(1) R&D per employee	(2) Share of product innovators	(3) Rate of growth of profits
R&D per employee (lagged)	0.46 [0.06]***	2.69 [0.28]***	
Rate of growth of profits (lagged)	0.18 [0.07]**		
New market objective	0.07 [0.03]**		
Distance from the frontier	0.01 [0.02]		
Share of product innovators			0.38 [0.10]***
New machinery per employee			0.82 [0.36]**
Rate of growth of sales			0.50 [0.20]**
Constant	−0.92 [1.49]	24.80 [1.42]***	−14.13 [3.30]***
Obs	204	204	204
RMSE	5.27	16.07	17.71
Chi-2 (p-value)	130.80 (0.00)	86.48 (0.00)	38.45 (0.00)

S.e. in brackets
Source: USD S.e. in parenthesis. *significant at 10 %, **significant at 5 %, ***significant at 1 %

In the first equation, as expected, R&D is path dependent, is pulled by demand, and is finance constrained, with profits playing a supporting role. The only coefficient that does not meet our expectation is the distance from the frontier which is not significant. In order to explore this variable a graphical examination is provided below

In the second equation product innovation is driven by lagged R&D alone. In the third equation product innovation and the adoption of new technology, together with sales growth, explain the variance of the growth rate of profits

These results are consistent with those found in the previous version of our model (Bogliacino and Pianta 2012), and with those of Table 3 above. The inclusion of demand variables strengthens the explanation of new products in (2)

In (1) the distance from the frontier of labour productivity does not emerge as significant (the same is in Table 3 above). In order to explore in greater detail this variable, we can examine it graphically. If we regress R&D per employee on its lag and we take the residuals, we can plot their distribution for different intervals of the distance. In order to choose the threshold for the distance from the frontier variable, we first look at the distribution of the distance and we see that it is bimodal, with a first mass of probability between 0 and 20 %. Then we plot the empirical density of

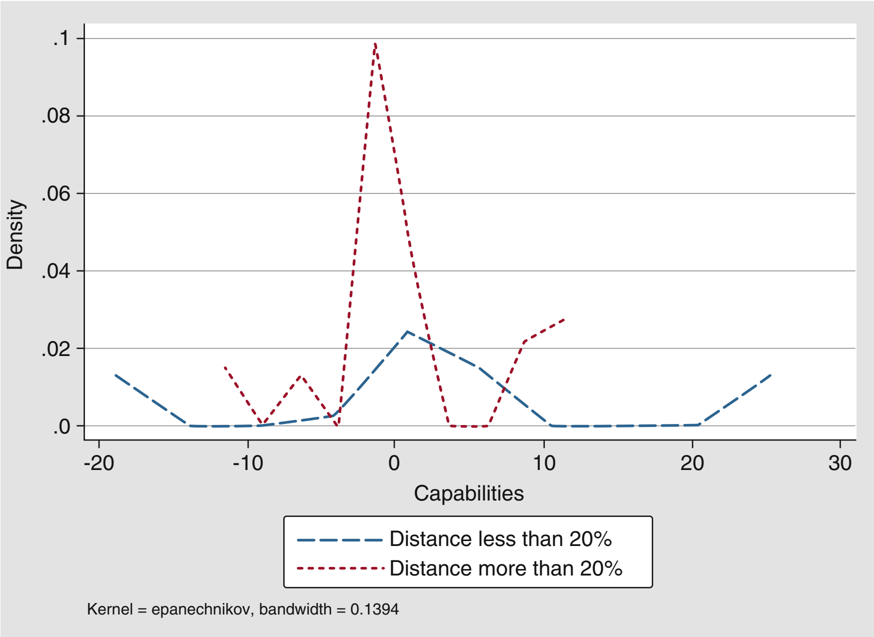

Fig. 1 The density of R&D for different value of the capability proxy

the residuals for the distance from the frontier below and above 20 %. The results are shown in Fig. 1 below. As we can see from the graph, for distances lower than 20 % (closer to the frontier) there is higher R&D expenditure and—one would say—higher right tail skewness. However, for distances less than 20 % there is also much more variability in the distribution of R&D expenditure. This evidence contributes to explain the lack of significance for this variable in the model

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