2015

The virtuous circle of innovation in Italian firms

Francesco Bogliacino, *Universidad Nacional de Colombia*
Matteo Lucchese
Leopoldo Nascia
Mario Pianta

ISSN 1974-4110 (on line edition)
ISSN 1594-7645 (print edition)

Università degli Studi di Urbino "Carlo Bo"
Facoltà di Economia
www.econ.uniurb.it

WP-EMS
Working Papers Series in
Economics, Mathematics and Statistics

THE VIRTUOUS CIRCLE OF INNOVATION IN ITALIAN FIRMS

Francesco Bogliacino Universidad Nacional de Colombia
Matteo Lucchese ISTAT and Università di Urbino
Leopoldo Nascia ISTAT
Mario Pianta Università di Urbino

WP-EMS # 2015/04

The virtuous circle of innovation in Italian firms

Francesco Bogliacino[1]
Universidad Nacional de Colombia

Matteo Lucchese
ISTAT and Università di Urbino

Leopoldo Nascia
ISTAT

Mario Pianta
Università di Urbino

Abstract

The "virtuous circle" between innovative inputs, outputs and economic performance is investigated in this article with a three equation model highlighting feedback loops and simultaneous relations. An empirical test is carried out considering innovative expenditure, innovative turnover and economic results in a sample of Italian manufacturing firms which are 'serial innovators'. We use data for the period 2000-2008 from a rich panel of Italian firms over 50 employees drawn from ISTAT, the National Institute of Statistics, including data from three waves of Community Innovation Surveys. The model we use extends the one developed at the industry level by Bogliacino and Pianta (2013a, 2013b), confirming previous findings. For the – rather limited – core of Italian persistent innovators, results show the complex links at play, the lags in the effects of innovative efforts, and the feedbacks between economic success and the ability to sustain innovation expenditure.

Keywords: Innovation, economic performance, three equation model, Italian firms

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

[1] Corresponding author. Email: francesco.bogliacino@gmail.com. Universidad Nacional de Colombia, Carrera 30, No 45-03, Bloque 311, Oficina 12B, Bogotá (Colombia), tel: (+57)-1-3165000, ext 12431

1. Introduction[2]

The relationship between innovation and performance in firms is investigated in this article moving beyond approaches that consider unidirectional causal links and building on evolutionary insights that emphasise the importance of cumulative processes and lags, the presence of feedback loops and complex, simultaneous interactions (Schumpeter, 1955; Dosi and Nelson, 2010).

We develop a model on innovation inputs, outputs and performance that accounts for the "circular" nature of this process. Firms carry out innovative expenditure, facing the cost of improving their products and processes; a qualitative change in output – with innovation-related sales – is the result of such new accumulation of knowledge; larger sales – and Schumpeterian profits – result from such innovation-related output, which in turn can sustain firms' innovative expenditures. Such a "virtuous circle" is at the root of economic dynamics and sustains the mutual interactions between innovation and performance.

While a large literature has addressed their relationships – usually with a one-way approach from the former to the latter – and several structural models have been developed, few studies have approached this issue in an integrated way, modelling the existence of "virtuous circles" and testing them with an empirical investigation.

We start from the model of Bogliacino and Pianta (2013a) - developed at the industry level - where industries' R&D efforts lead to successful innovations, new product sales lead to high Schumpeterian profits, which in turn provide resources for funding R&D efforts. The model - based on three simultaneous equations – has been tested on manufacturing and services industries of major European countries, showing that such cumulative effects and feedback loops can indeed account for the industry dynamics of the last two decades (see also Bogliacino and Pianta 2013b and Guarascio, Pianta and Bogliacino 2015).

In this article we want to bring the same approach to the firm level, exploring whether the same "virtuous circle" of technology-driven growth can be identified in the enterprises where knowledge is accumulated, innovations are introduced and market success is obtained. The empirical test of the model we propose for firm-level analysis is carried out considering innovative expenditure, innovative turnover and economic results in a sample of Italian manufacturing firms, which are persistent innovators. We use data for the period 1998-2008 from a rich panel of 908 Italian firms over 50 employees drawn from ISTAT, the National Institute of Statistics, including data from three waves of Community Innovation Surveys. We select the group of 143 firms that are "serial innovators", i.e. those firms that introduced a product innovation in the three CIS waves 1998-2000, 2002-2004, 2004-2006.

Results show that findings at the firm level replicate those obtained for industries by Bogliacino and Pianta (2013a, 2013b). Innovative efforts are cumulative – but also volatile - and supported by high turnover; new product success results from innovative expenditure and demand pull effects; overall firms' turnover is fuelled by innovative sales alongside other factors of competitiveness. Cumulative processes and feedbacks indeed shape the "virtuous circle" of innovation in firms.

[2] Versions of this work have been presented at workshops at Sapienza University of Rome, University of Trento and ISTAT. We thank participants and in particular Davide Castellani, Giovanni Dosi, Alessandro Zeli; we thank ISTAT for data access.

This article proceeds as follows. Section 2 presents a review of the literature, paying special attention to contributions based on Italian data. Section 3 introduces the dataset, the model and the methodology. Section 4 shows the results; section 5 concludes.

2. The literature on innovation and performance in firms

Most of the literature analyzing the microeconomic relationships at the root of innovation-driven-growth has focused on unidirectional links. Some studies have estimated the impact of R&D and innovation output (usually patents) on firms' economic performance (Bottazzi and Peri, 2007; Crafts and Mills, 2005; Lanjouw and Schankerman, 2004; Bloom and Van Reenen, 2002). Others have explored the role of profits in driving innovation at firm level (Teece, 1986, Geroski et al. 1993, Cefis and Ciccarelli, 2005) or at industry level (Klepper, 1997); some others have studied the role of profits in overcoming the financing constraints for R&D (Hall, 2002; Cantwell, 2002; O'Sullivan, 2005; Coad and Rao, 2010; Bogliacino and Gómez, 2014; Cincera and Ravet, 2010). However, few studies have addressed the "black box" of the innovation process in an integrated way, accounting for the complexity of inter-relations.

The model of Crépon et al. (1998) (the so-called CDM model) has proposed to investigate the contribution of innovation to productivity by means of a three step model, in which R&D is driven by size, demand pull and technology push factors; a knowledge production function relates the amount of resources firms decide to invest in R&D to an innovation output; the latter impinges upon firm performance (usually productivity) through a standard Cobb-Douglas function. Designed to work with survey data and equipped to consider different types of innovation output, this model provides a sequential structure to describe the process behind the innovation activity of firms. An example of application is in Mairesse and Mohnen (2002); an extensive review of the application of this model to innovation surveys is in Mairesse and Mohnen (2010); a similar approach but tailored on a different data source is in Parisi et al. (2006). Using a large unbalanced panel data of Italian manufacturing firms in the 1995-2006 period, Hall et al. (2012) have extended the CDM model to include ICT expenditure as a determinant of the innovation output; they attempt to identify a set of channels through which ICT and R&D investments affect innovation among firms as well as the (indirect) effect on firm productivity. Hall et al. (2009) use a similar CDM framework to estimate the dynamics of Italian SMEs, where typically R&D can undervalue their effective innovative efforts.

Although the CDM model represents an improvement in understanding the complexity of innovation, it shares several weaknesses of neoclassical views on the operation of firms – seen as homogeneous units - and innovation, including an indifferentiated view of innovation, with no distinction between different strategies, such as those mainly relying on new products or on new processes. Moreover, the sequential process described in the model neglects simultaneity and feedback effects among variables, and disregards the cumulative processes of innovation in firms.

Evolutionary studies provide a more convincing framework for investigating innovation processes in firms (Dosi and Nelson, 2010; Dosi, 2012). They have shown that growth is characterized by persistent firm heterogeneity, and by cumulative processes that are specific to firms sharing specific characteristics in their knowledge base and business strategies (Dosi et al., 2010). Several studies in this perspective have investigated the

dynamics of innovation, growth and productivity of Italian firms. Building on longitudinal micro-evidence on Italian manufacturing firms, Dosi (2007) explored the rich statistical structure of industrial evolution. By examining the basic features of distributions of firms - in terms of their size, growth and profitability - Dosi highlighted the underlying inter-firm heterogeneity that persist over time as an empirical validation of evolutionary theories. The idiosyncratic components of firms - principally their innovation efforts - drive the process of change in such distributions. However, the process of market selection appears to play a minor role in affecting the patterns of growth of firms as differential efficiencies do not reward more successful firms in terms of growth.

A large dataset on Italian manufacturing microdata produced by ISTAT – the same one we use in our investigation in this article – has allowed novel insights into the dynamics of firms and innovations. Bottazzi et al. (2010), using such data for 1989 to 2004, showed that "the survival of the fittest" is barely observable: more profitable firms do not grow systematically more than less productive one. Using the same dataset, Dosi et al. (2012) confirmed the intra-sectoral heterogeneity of firms in terms of labour productivity and growth rates; however, they observe that the distribution of labour productivity has not significantly changed over time and no relevant change in patterns seem to be associated to the introduction of euro. For Italy, they identified a "neo-dualism" where a small group of dynamic firms coexists with a large group of laggard, less innovative firms.

The same ISTAT panel has been used by Oropallo and Rossetti (2011) for the period 2001-2008, finding a strong effect of productivity on export, but a lack – at the same time - of the "learning by exporting" effect on firms. Milana et al. (2013) using DEA techniques for the period 1998-2004 analysed the stagnation of productivity in many industries, finding higher efficiency gains and stronger performances of larger firms compared to SMEs. Nardecchia et al. (2011) confirmed the low productivity of Italian firms, while Velucchi et al. (2011) documented the increasing heterogeneity of productivity performances in the 1998-2007 period.

Several studies – using a variety of approaches - have looked at the factors that can support or hinder the competitiveness of Italian firms. Pellegrino et al. (2012) showed that Italian young innovative companies (indicated as the solution to Europe's low R&D in Cincera and Veugelers, 2010) lack a significant R&D activity and rely more on external sources of innovation. Bugamelli et al. (2011) identified the roots of Italy's productivity stagnation in the persistent smaller size (compared with European and OECD averages) and in the obsolete organizational and managerial routines. The role of employment protection in limiting firms' competitiveness – comparing behaviours of firms above and below the threshold for the enforcement of workers' rights - seems to play a largely negligible role (Boeri and Jimeno, 2005). The more complex pattern of vertical disintegration of production in Global Value Chains has been explored by Agostino et al. (2011) finding that key suppliers have an export premium in their productivity performances. An export premium is documented also in De Nardis and Pappalardo (2011).

Innovation and profits have been studied by Bartoloni (2012), using data from three waves of the Italian CIS and administrative sources for the period 1996-2003, finding an important influence of innovation on profitability, as well as a strong innovation persistence. The same persistence has been found by Antonelli et al. (2012). Finally, the micro level study by Castiglione and Infante (2013) pointed out the positive impact of the use of ICTs on total factor productivity of Italian firms, affecting the composition of firms' investments, firm organisation and learning by doing.

3. Data, model and methodology

3.1. The ISTAT panel

The data used in the empirical investigation of this article comes from the panel developed by ISTAT (the Italian Institute of Statistics, see Nardecchia et al., 2010; Biffignandi et al. 2009) with yearly data on firms for the period 1998-2007. The panel design is based on the matching of survey microdata with administrative sources in order to ensure integration of not respondents and continuity over time. The implementation of the panel included four relevant sources: the Istat Business Register of Italian firms (ASIA), the Italian Structural Business Statistics survey (SCI), focusing on economic data of firms with more than 100 employees, the Italian Survey on Small and Medium Sized Enterprises (PMI) focusing on the firms with 20-100 employees and the database on balance sheets of incorporated firms collected by the Central Balance-Sheet Data Office of Italy.

In order to include business transformations like mergers and acquisitions (M&A) the panel follows a backward perspective. The panel has established all links between firms in the 1998 survey with 2007 survey respondents, including business transformations; the panel however does not include new firms entering the market after 1998. The features of the panel are compatible with the requirements of information that is complete, consistent and comparable over time (Kessler and Greenberg, 1981).

Such business survey data have been integrated with information for the same firms drawn from Community Innovation Surveys, R&D surveys and trade data. Each firm is originally associated with an industry defined by the Nace Rev. 1.1 classification, based on its main economic activity.

All variables are originally measured at current prices in euro and transformed in year 2000 prices. Output volumes have been deflated using indexes of producer prices at industry level. Capital values have been deflated by means of the price index for investment goods, whereas the variables related to employment such as labour cost have been deflated by means of wage and salary indexes for each NACE category.

The ISTAT panel of firms over 20 employees includes 70,000 units in 1998 and more than 82,000 units in 2007, basically covering the population of firms over 20 employees (Biffignandi, Nascia and Zeli, 2009). For this article, the original ISTAT panel has been extended to include CIS 2006 data for all firms, allowing a deeper characterisation of innovative activities.

From the ISTAT panel we have extracted a database that includes the firms that are relevant for our investigation and: a. belong to manufacturing industry; b. have more than 50 employees – a minimum threshold for carrying out relevant innovative efforts; c. have answered to three waves of the Community Innovation Survey (CIS): CIS 3 (1998-2000), CIS 4 (2002-2004) and CIS 5 (2004-2006).

The number of firms which satisfy such three conditions is 908; they include 323 enterprises that did not introduce innovations or carried out process innovations only; 442 firms that are ‘occasional innovators’, introducing new products in one or two CIS surveys out of the three surveys considered; 143 firms that are ‘serial innovators‘ introducing product innovations in all the three CIS surveys considered. The latter group will be the focus of our investigation on the relationships between innovative input, output and performance, as these are the firms where innovation is systematic and highly relevant in

shaping economic outcomes. When all firms are considered, the large numbers of non innovators or occasional innovators tend to cloud key relationships; their behaviour and strategies do not rely on innovation as a relevant factor.
Our study considers the following variables:

- **Innovative expenditure** (***InnExpend***, drawn from CIS and R&D survey data) is defined as the sum of in house and external R&D, acquisition of machinery, equipment and software, and acquisition of external technologies. As a measure of innovation inputs the variable we use is *innovative expenditure per hour worked,* since hours worked are generally considered as the best indicator of labour input in firms.
- **Innovative turnover** (***InnTurn***, drawn from CIS) is the share of turnover due to new or significantly improved products, both for the firm than for the reference market. The variable we use is *innovative turnover per hour worked*, a proxy of the economic impact that innovations have.
- **Total turnover** (***Turn***) is the more general indicator for the economic performance of firms; it documents firm growth and market success, and is generally closely associated to profitability; the variable we use is *Total turnover per hour worked*.
- **Labour productivity,** (***π***) defined as *value added per hour worked*, is used as an overall indicator of efficiency reflecting factors such as capital, organizational models and market power.
- **Wage levels**, (***w***) defined as *total wages per hour worked*, provide information on the skill level of employees but, at the same time, represent a cost and an incentive for the introduction of labour saving process innovations.
- **Exports,** (***Exports***) defined again as *export per hours worked*, are considered in order to account for demand pull effects on innovation
- **The degree of market power** (***Herf***) in the industry – at the three digit level of NACE – where firms have their principal activity has been calculated with an *Herfindal index* based on the number of employees as dimensional variable. As firms of our sample are distributed across a large number of NACE classes and are persistent innovators, we expect them to be among the 'leaders' of their respective industries, benefitting from a higher degree of market concentration.

Innovation and economic variables are referred to three periods (2000, 2004 and 2006). The first year (2000) is the base for the lagged variables affecting the second period (2004). The empirical test of the model will be based on the two periods, 2004 and 2006.
Some descriptive evidence is provided by Table 1, showing the average values of the main variables in 2004 and 2006 for the whole sample, occasional and serial innovators. Firms that have persistently introduced new products account for 16% only of the whole sample, although about one half are occasional innovators. Average values are stable across the two periods. As expected, serial innovators show higher innovative expenditures per hour worked, and a greater innovative turnover, but a lower than average total turnover per hour worked, that may be affected by a greater vertical integration of innovating firms. The economic performance variables show that serial innovators are much more export-oriented than other firms (export per hour worked is more than 15% higher than for the total sample of firms), but do not show significant differences in productivity, and even less in wages.
Most variables show an improvement of performances from 2004 to 2006, with export 'pulling' the growth of total sales and innovative turnover; such benefits of growth,

however, are hardly visible in terms of productivity and wages. Data also suggests that there are modest differences between occasional innovators and non innovators. Serial innovators are mainly located in the Northern Italy, they principally operate in science based and specialised suppliers industries, with some presence of firms from scale intensive and traditional sectors.

Looking at the distribution of variables, additional elements emerge. For innovative expenditure the expected persistence of levels of efforts over time is confirmed, but is combined with a substantial volatility when innovative expenditure per hour worked is considered. This is due on the one hand to the discontinuous nature of innovative projects; on the other hand the very success of a new product may lead to an expansion of hours worked for production, leading to a lower ratio in the following period. Figure A1 in the Appendix shows the absolute differences in innovative expenditure per hour worked for 2000-2004 and 2004-2006, indicating each firm with the code of the Pavitt classes they belong to. Alongside a general persistence, we find a negative pattern especially for firms in the Science based and Specialised suppliers classes, where both factors pointed out above may be particularly relevant.

Table 1. Innovation and performance in a panel of Italian manufacturing firms
Economic variables are expressed in euros per hour worked in constant 2000 prices

	2004			2006		
	Total firms	**Occasional innovators**	**Serial innovators**	**Total firms**	**Occasional innovators**	**Serial innovators**
Number of firms	908	442	143	908	442	143
Total turnover	202.4	225.1	163.6	212.8	233.2	175.5
Innovative turnover	20.8	18.8	41.5	18.4	13.5	43.5
Innovative expenditure	3.9	3.6	6.6	4.5	4.7	6.2
Wages	15.6	15.9	15.8	15.9	16.1	16
Export	61.4	57.2	74.8	66.6	62.4	77.1
Productivity	41.4	42.9	40.4	39.6	40.3	41.3

3.2.The model and econometric strategy

The model we propose here is an extension of the one developed in Bogliacino and Pianta (2013a) where a simultaneous three equation model is estimated – at the industry level - linking innovation inputs, innovation outputs and economic performance, considering the presence of cumulative processes and feedback loops. The model is tested on 38 manufacturing and service sectors of eight European countries; two time periods are investigated here. The interest of replicating a similar model at the firm level is in the

coherence in the understanding of the innovation process we may obtain by looking with the same approach at industry and firm level dynamics. The "virtuous circle" of innovation has its roots in dynamic firms – hence the choice to focus on serial innovators - which collectively drive the processes of structural change detected at the industry level. If the same cumulative processes, lags and feedback loops are identified at both levels of analysis, we can really argue that the evolutionary approach to innovation is able to capture the fundamental mechanisms of change in our economies.
The model we propose for investigating the "virtuous circle" of innovation in firms is the following:

$$\begin{aligned} Turn_{it} &= \alpha_0 + \alpha_1 InnTurn_{it} + \alpha_2 \pi_{it} + \alpha_3 w_{it} + \varepsilon_{it}^1 \\ InnTurn_{it} &= \gamma_0 + \gamma_1 InnExpend_{it-1} + \gamma_2 Export_{it} + \gamma_3 Herf_{it} + \varepsilon_{it}^2 \\ InnExpend_{it} &= \beta_0 + \beta_1 InnExpend_{it-1} + \beta_2 Turn_{it} + \beta_3 w_{it-1} + \varepsilon_{it}^3 \end{aligned} \qquad (1)$$

The variables considered in the model are the ones listed above; economic variables are all expressed in euros per hour worked, in order to account for the different size of firms.
In the first equation, we identify the elements that contribute to the turnover of firms, used as a proxy of overall economic performance. As well known, at the micro level demand is not a constraint to the growth of firms, as a company can grow at the expense of others through business stealing. The main determinants can therefore be found on the supply side, and we consider:
1) innovative performance, captured through innovative turnover, which documents the market success of innovation and growth through technological competitiveness;
2) overall efficiency, resulting from investment, organisation, etc., captured through hourly productivity;
3) workers' skills, competences and efforts, reflected in wages – in an efficiency wage perspective - and proxied by hourly wages (Shapiro and Stiglitz, 1984). At the same time, wages could have a negative effect on turnover when firms rely on cost competitiveness for their growth; as we consider persistent innovators, we can expect that this factor has a minor effect.
The second equation explains the innovative performance of firms, proxied by innovative turnover. Independent variables include lagged innovative expenditure, accounting for total innovation inputs; export intensity, a variable that includes the demand pull effect of exports on innovation success and the importance of larger markets for exploiting innovative capabilities and dynamic increasing returns (Kaldor, 1981, 1972); finally we include the measure of industry concentration, capturing the possibility to extract rents from positions of market power.
The third equation considers the determinants of innovative expenditure, a measure of overall innovative efforts. They are a function of:
1) lagged innovative expenditure, that reflect the cumulative nature of technological change in firms, capturing technology push effects and the path dependence nature of innovation (Mowery and Nelson, 1979);
2) total turnover that reflects the importance of firm size and, indirectly, the demand pull effect on technological efforts (Piva and Vivarelli, 2007; Kleinknecht and Verspagen, 1990; Schmookler, 1966);

3) wages, which are associated (possibly with a lag) to higher innovation through two effects: on the one hand, higher wages are related to higher skills of workers, reflecting knowledge that is complementary to innovative efforts in firms; on the other hand, higher wages may induce greater effort for labour saving innovation through a Ricardo-Sylos Labini effect (Ricardo 1919; Sylos Labini, 1984).

All variables are normalized through hours (except for the Herfindhal index) to account for size. The error term is in standard components form, i.e. including both time invariant and time variant part.

The system in (1) can be consistently estimated by OLS if the regressors satisfy strict exogeneity (Wooldridge, 2002). By strict exogeneity we mean that the expected value of the error term conditioned on both lags and leads of the regressors should be zero. In other words, the introduction of a panel structure requires (for OLS to be unbiased) not only the standard exogeneity requirement, but also that there are no feedback effect.

The identification assumption is very unlikely to be satisfied for two reasons: 1) the regressors may be correlated with the time invariant component of the error (violating exogeneity); 2) since we have cross equations restrictions with a lag structure, feedback effects are very likely.

The first step to identify the effects is to remove the time invariant part of the error term. This can be done by removing the mean of each variable at the firm level. This is called Within Group estimation or Fixed Effects. By removing the time invariant part we are implicitly rescaling the data at the firm level and using the variation around the individual mean as the information to estimate the effect.

As shown by Wooldridge (2002) and Arellano and Bond (1991), once we transform the data through First Differencing, we eliminate two sources of problems: on the one hand we eliminate the time invariant part of the error component term; on the other hand we eliminate the feedback effect and we can identify the effects of the regressors if they are predetermined. As a result, we first differentiate the data and then we run two stages least squares. We estimate the system jointly to increase efficiency of the estimates.

We proceed by steps, first showing OLS, then Fixed effect estimation and finally First Difference estimation.

Finally one last issue for identification concerns selection bias. In our model we consider those companies which are persistent innovators and engage systematically in innovation. However, in the full sample of companies, there are firms who introduce new products occasionally. If the selection is related to some unobservable, then the coefficients may be biased; alternatively, we postulate that it is the “virtuous circle” of innovation, which explains capabilities and innovative performance. Our hypothesis is in line with the literature on increasing returns, which shows that the dynamics of increasing returns is self-sustaining and it is not driven by some preliminary or pre-existent characteristic of the firm (Arthur, 1989).

To empirically assess our hypothesis, we conduct a series of t-tests on the characteristics of occasional and persistent innovators on the data at the beginning of the period (thus not influenced by the innovative activity), allowing for unequal variances. The equality between the two samples is not rejected, suggesting that even pure chance may move a firm from the occasional to the persistent innovator, but once belonging to the latter group, companies enjoy the dynamics of increasing returns and are able to achieve innovative and economic performance. The t-test for equality of the sample in 1998 (before the treatment) are -.55 (p value .58) for the total turnover, .78 (p value .43) for the profits, -.91 (p value

.36) for the value added, -.39 (p value .69) for the hourly wage, and -1.39 (p value .26) for the export. We allowed for unequal variances. In all cases the null hypothesis of equality is not rejected.

4. Results

4.1 Baseline regression

In Table 2 we report the baseline estimation. We run Seemingly Unrelated Regression (SURE), which is unbiased under the same conditions of OLS but it more efficient. As we discussed in Section 3, these results are not robust because the identification assumptions are not met by this model, but help us introducing the general relationships among the variables.

Table 2. Baseline regression. Seemingly unrelated regression estimation.

Dependent Variable	Total turnover per hour	Innovative turnover per hour	Innovative expenditure per hour
Total turnover per hour			0.01 (0.00)***
Innovative turnover per hour	0.76 (0.10)***		
Innovative expenditure per hour (first lag)		1.33 (0.50)***	0.45 (0.05)***
Hourly wage	4.39 (0.75)***		
Hourly wage (first lag)			0.1 (0.04)**
Hourly productivity	1.27 (0.28)***		
Export per hour		0.33 (0.04)***	
Herfindal index		47.9 (26.15)*	
R2	0.81	0.44	0.61
Chi2	1127.45***	201.12***	393.90***
No. Obs.	242	242	242

Source: Selection from ISTAT Panel of Italian Firms (all firms above 50 employees).
*, **, *** stand for significance at 10, 5 and 1 percent.

The innovative "virtuous circle" clearly appears in the results. In the first equation, turnover is driven by innovative sales, productivity and wages, as discussed above. A high innovative turnover directly affects total sales, supporting firm growth and market shares. Productivity and wages equally support sales growth through greater efficiency and complementarities with workers' skills.

In the second equation, innovative turnover is affected by lagged innovative expenditure - more than proportionally – as well as by exports and market power. The close link between

innovation inputs and outcomes is confirmed; exports show again a crucial 'pull' effect on innovative sales; a high market concentration has a positive effect on innovative turnover as the dominant market position of our persistent innovators means that they can more easily obtain market success of their new products.

Finally, in the third equation innovative expenditures are the result of: (1) cumulative processes – with the lagged variable having a major influence; (2) the influence of total turnover which reflect the possibility to overcome cash constraints in the financing of innovative efforts; (3) the positive role of lagged wages, reflecting the two distinct mechanisms pointed out above; on the one hand the complementarity with workers' skills and on the other hand the innovation push effect of the search for labour-replacing new processes.

4.2 Robust estimation

The next step in our econometric strategy is to move to robust estimations. We first eliminate the time invariant part of the error term, though Within Group transformation. The system is still run jointly for efficiency reasons.[3] Results are reported in Table 3.

Table 3. Baseline regression. Fixed effect estimation.

Dependent Variable	Total turnover per hour	Innovative turnover per hour	Innovative expenditure per hour
Total turnover per hour			0.02 (0.00)***
Innovative turnover per hour	0.16 (0.03)***		
Innovative expenditure per hour (first lag)		1.42 (0.84)***	-0.58 (0.06)***
Hourly wage	5.61 (0.02)***		
Hourly wage (first lag)			0.35 (0.16)**
Hourly productivity	1.31 (0.16)***		
Export per hour		0.14 (0.08)*	
Herfindal index		-93.14 (18.30)***	
R2	0.43	0.11	0.26
Chi2	180.66***	31.41***	88.86***
No. Obs.	242	242	242

Source: Selection from ISTAT Panel of Italian Firms (all firms above 50 employees).
*, **, *** stands for significance at 10, 5 and 1 percent.

[3] The method used for the results shown in Table 3 is a SURE estimation with a transformation of variables through a within group operator, which eliminates the average value per company through time. We still leave the Herfindal Index in level to allow for some dynamic structural effect. In any case estimations are not affected.

Once controlled for heterogeneity, some coefficients are reduced in magnitude, but the presence of the "virtuous cycle" of innovation is still confirmed. In the first equation all variables maintain their significant effects on total turnover; innovative sales play an important role; higher wages are associated to higher sales; hourly productivity supports the market expansions of firms.
In the second equation innovative turnover is mainly determined by past innovative expenditure with a more than proportional effect, exports remain relevant, while market power reverses its sign. One possible explanation for the latter result is that in shaping the success of new products, market power is now less important than the competitive dynamics in relevant industries when the estimation excludes the idiosyncratic elements of firms.
Finally, in the third equation the positive role of total turnover – reflecting the ability to finance innovation efforts – is confirmed, alongside with the complementarity between high lagged wage and innovative effort. The coefficient for the lagged innovative expenditure turns negative and significant, suggesting that the cumulative nature of technological efforts is now less relevant than the volatility observed in the distribution (see Figure A1 and the discussion above). Moreover, there is also an econometric explanation: fixed effects cannot estimate consistently the autoregressive term and asymptotically the coefficient is biased downwards. Since we do not have enough information time-wise, we cannot apply GMM and identify correctly the autoregressive term.

As a test of robustness we carry out a further estimation that checks for omitted variables in the innovation expenditure equation, including firm size (number of hours worked) and industry concentration (Herfindal index). The results –in Table A1 in the Appendix – show that the two variables are not significant and the coefficients do no change.

Finally, we carry out an estimation in First Differences. Under First Difference estimation, we require only that the regressors are predetermined. This weakens significantly the hypothesis under which we identify the coefficients. Again, for efficiency, we transform the data and run the system jointly; the number of observation is reduced since we use only variation from one wave to the other. In order to increase the number of instruments, we include also the second lag of all the variables in level and the industry dummies. Using the variable in level as instrument for the change is the standard practice in GMM estimation, thus our methodology is very robust. Results are reported in Table 4; an additional test has been carried out on simple First Differences, finding the same results.
The first equation is unchanged; turnover is driven by innovative sales, high wages and productivity. The second equation shows that innovative turnover is driven by lagged innovative expenditure and exports, while industry concentration loses its significance. The third equation shows that innovative expenditures are driven by total turnover – supporting the financing of innovative efforts – and by higher lagged wages; the negative link between past and present innovative efforts is found again, confirming the volatility effect already discussed.
The results of Table 4 are the most robust specification; using some simple algebra, we can give an account of the effect size of each variable. Since this is a linear model, we can express the magnitude of the effect in percentage of one standard deviation of the dependent variable, once allowing the independent variable to vary by one standard deviation. In the turnover variable, the stronger effect is that of hourly productivity - a

change of one standard deviation increases sales per worked hour by 38% of its standard deviation. Hourly wages and and innovative expenditure follow, with increases in sales respectively of 26% and 18% of its standard deviation. In the second equation innovative turnover is affected by exports - a change of one standard deviation increases innovative sales per worked hour by 20% of its standard deviation – and by innovative expenditure with a 12% impact. Finally, in the third equation, innovative expenditure per hour are mainly affected by total turnover – a change of one standard deviation in sales per hour worked leads to an increase in innovative expenditure by 23% of its standard deviation.

Table 4. Baseline regression. First difference, two stages least squares estimation.

Dependent Variable	(Delta) Total turnover per hour	(Delta) Innovative turnover per hour	(Delta) Innovative expenditure per hour
(Delta) Total turnover per hour			0.03 (0.02)*
(Delta) Innovative turnover per hour	0.22 (0.11)**		
(Delta) Innovative expenditure per hour (first lag)		1.74 (1.00)*	-0.52 (0.15)***
(Delta) Hourly wage	5.59 (1.49)***		
(Delta) Hourly wage (first lag)			0.50 (0.30)*
(Delta) Hourly productivity	1.31 (0.24)***		
(Delta) Export per hour		0.28 (0.13)**	
Herfindal index		-9.11 (29.53)	
R2	0.43	0.06	0.14
F-stat	27.71***	2.42*	5.10***
No. Obs.	110	110	110

Source: Selection from ISTAT Panel of Italian Firms (all firms above 50 employees). Added Instruments: industry dummies, second lag of all variables in level.
*, **, *** stands for significance at 10, 5 and 1 percent.

5. Conclusions

This article has investigated the existence of a circular relationship and feedback loops between innovative input, output and firm performance. The simultaneous model we have proposed is characterised by the relationships summarised in Figure 1 below. Firms carry out innovative expenditure – including R&D, technology adoption, acquisition of new machinery and other activities - on the basis of previous innovative inputs, total turnover – which represents a key source of funds for innovation, reducing financial constraints – and

wages, reflecting workers' competences that are crucial for carrying out innovation. Second, innovative efforts lead to new products whose sales are also driven by exports through the role of 'demand pull'. Third, innovative sales lead to higher turnover – and improved overall performance, including profits – alongside productivity and wages. This 'virtuous circle' of innovation is portrayed in an original way by our model, improving on previous literature that has investigated some of these links in isolation or in a sequential way. Our model extends at the firm level the model and empirical investigation carried out by Bogliacino and Pianta (2013a, 2013b) on manufacturing and service industries for the main European countries.

The empirical test on data for Italian manufacturing firms that have been persistent product innovators in the 2000-2006 period has shown that this 'virtuous circle' of innovation is indeed shaping the microeconomic dynamics of innovation. While the expectations of our model are confirmed, four results deserve specific consideration.

First, innovative efforts are shaped by the well known cumulative nature of technological change, but when firms are investigated over a short time period, significant volatility of annual expenditure also emerges, due to the discontinuous pattern of innovative projects; this was documented in our analysis of data in Figure A1 in the Appendix and has been captured by fixed effects and first differences models. Cumulative and path-dependent effects are therefore more visible when studies are carried out at the industry level or on panels of firms covering a larger time span.

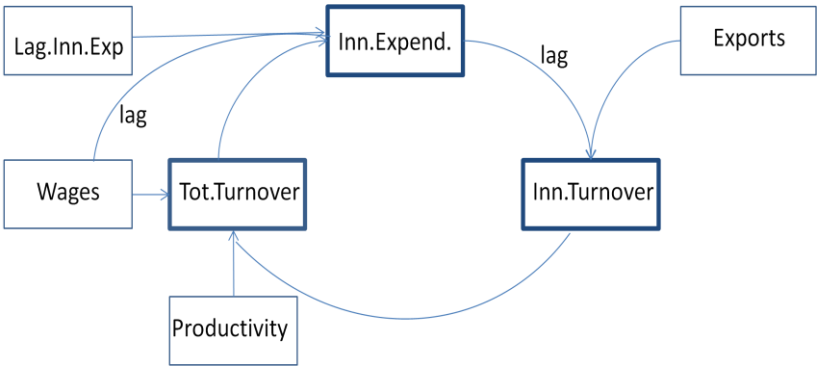
Second, the role of wages – that has been largely neglected in previous innovation studies – emerges with an important influence both on innovative expenditure (with a lag) and on total turnover of firms. In firms that have been regularly introducing new products – as the ones in our panel - wages cannot be considered mainly as a cost, but reflect workers' skills and competences that are necessary for the introduction of innovation and for the very growth of firms. For such firms, in fact, higher sales are driven by a technological competitiveness based on new knowledge and new products, rather than by lower costs and wages that may sustain a short-sighted strategy of cost competitiveness (Pianta, 2001).

Third, the role of market power is less straightforward than expected, as suggested by a substantial literature. A higher market power allows firms' greater success in the sales of new products, but this relationship is lost when the heterogeneity of firms' characteristics is considered.

Fourth, the role of demand – again an aspect that is often neglected in the innovation literature – also emerges from our findings. As pointed out in section 2, at the firm level demand constraints are less relevant, as enterprises can grow through business stealing. Although success in innovation and exports can be driven by the same characteristics of a firm, our results highlight the specific role that export demand plays – with its 'pull' effect - in driving market success of new products; the role of exports in the innovative 'virtuous circle' has been further investigated at the industry level by Guarascio, Pianta and Bogliacino (2015). On the empirical front, we should point out that in Italy in the period considered, exports were the only dynamic component of demand in a generally stagnating economy.

While these relationships have usually been investigated with a one-way approach, we have developed an integrated perspective, accounting for the complexity of links and their feedback loops, leading to our model and empirical test of the "virtuous circles" of innovation.

Figure 1. The circular relationships between innovative expenditures, innovative sales and turnover



A few general lessons on the analysis of firms and industries emerge from our work. The focus on serial innovators has meant that we can explore the specific characteristics of firms that regularly carry out innovative efforts and introduce new products. Most of the innovation literature – including evolutionary perspectives - has studied the innovation process in the generality of firms, identifying the characteristics of innovative enterprises as opposed to the rest of firms. Due to the high heterogeneity of firms, ownership structures, competences and strategies, these studies have generally found weak relationships between innovation and business growth. Conversely, in our sample we focus on persistent innovators that share a systematic involvement in innovation related activites and represent the more dynamic component of manufacturing industries. In this sample we can identify the emergence of specific relationships between innovation input, output and performance.
However, considering the empirical investigation on Italian firms, it should be pointed out that the 'virtuous circle' of innovation we identified operates in a rather small group of persistent innovators – 143 firms in the whole ISTAT database. This means that the innovative dynamics is far from shaping the overall evolution of Italian industry, where different 'low path' strategies – relying on process innovation, low wages and cost competitiveness – tend to prevail (Crespi and Pianta, 2008).
An important finding and a major novelty of this article is the coherence in the modelling we propose for innovative 'virtuous circles' at the firm and at the industry level. As pointed out in section 1, we started from the industry level model - based on three simultaneous equations – of Bogliacino and Pianta (2013a), where industries' R&D drives innovative turnover, that leads to high Schumpeterian profits, which in turn can fund R&D. In this article we found that the same cumulative effects and feedback loops shape the innovative 'virtuous circle' that characterises the most dynamic firms in Italy in the 2000-2006 period.
The specificities of studies at the industry and firm levels emerge from our work. A first question is the role of demand; total demand for industries is constrained by the dynamics of the different demand components – exports, consumption and investment - and in

Bogliacino and Pianta (2013b) a specific investigation of their role has been developed. Conversely, in studies at the firm level, demand can be less relevant in shaping the dynamics of turnover, as firms can grow at the expense of other less efficient firms, even when an industry's aggregate output does not change. At the firm level a key role that demand plays consists of the 'pull' effect on innovative efforts and, in particular, on the success of new products that we found in our empirical investigation.

The diversity of innovative efforts – R&D on the one hand and technology adoption on the other – was important in the industry level analysis, as sectors are characterised by widely different innovative patterns. In this article the focus on persistent innovators means that firms share a common commitment to new product development and more similar technological strategies. Moreover, we are able to consider the aggregate of all types of innovation-related expenditure (including new machinery), moving beyond traditional concentration on R&D.

In fact, the presence of the 'virtuous circle' we identified, means that persistent innovators in Italy pursue a strategy of technological competitiveness relying on accumulation of knowledge, development of new products and use of internal resources for R&D efforts. In this process, the positive role played by high wages emerges in an important way – long disregarded by innovation studies - as they reflect the high skills that are crucial for the success of innovation. Therefore, one of the policy lessons we can draw from these findings is that a low wage policy is counterproductive for the 'virtuous circle' of innovation.

A final consideration – again with a strong policy relevance – is that the operation of the 'virtuous circle' requires that all its elements work effectively - knowledge and capabilities are developed; new products have market success; firms grow and profits are used to sustain innovative efforts. Failure in one of these connections means a much poorer impact of innovation or a 'virtuous circle' that involves – as in the Italian case – a rather small number of firms. These factors highlight the systemic nature of these dynamics and the importance of the national innovation system as a key policy framework for building successful relationships between innovation input, output and performance in firms.

References

Agostino, M., Nugent, J.B., Scalera, D., Trivieri, F., Giunta, A. (2011) Firm Productivity, Organizational Choice and Global Value Chain, Working Papers 2011R09, Basque Institute of Competitiveness

Antonelli, C., Crespi, F., Scellato, G. (2012) Inside innovation persistence: new evidence from Italian micro-data, *Structural Change and Economic Dynamics*, 23(4), 341-353.

Arellano, M., Bond, S., 1991. Some tests of specification for panel data: Monte Carlo evidence and an application to employment equations. Review of Economic Studies 58, 277–297.

Arrow, K. (1962) Economic welfare and the allocation of resources for invention,, in Groves, H. M. (Eds.): The Rate and Direction of Inventive Activity: Economic and Social Factors, NBER Books: 609-626.

Arthur, B. (1989) Competing Technologies, Increasing Returns, and Lock-In by Historical Events. *Economic Journal*, 99, 116-131

Bartoloni E., (2012) The persistence of innovation: a panel data investigation on manufacturing firms, International Review of Applied Economics, 26:6, 787-810.

Biffignandi S., Nascia L., Zeli A. (2009). Survey and Administrative Data Mix in a

Business Survey" presented at EESW09, European Establishment Statistics Workshop, 7-9 September Stockholm Sweden.

Bloom, N. and Van Reenen, J. (2002) Patents, real options and firm performance, *Economic Journal*, vol. 112, C97-C116

Bogliacino, F. and Gómez, S. (2010) Capabilities and investment in R&D: An analysis on European data, *Structural Change and Economic Dynamics*, Elsevier, vol. 31(C), pages 101-111

Bogliacino, F. and Pianta, M. (2013a) Profits, R&D and innovation. A model and a test, *Industrial and Corporate Change*, 22 (3): 649-678.

Bogliacino, F. and Pianta, M. (2013b) 'Innovation and Demand in Industry Dynamics: R&D, New Products and Profits', in A. Pyka and E.S. Andersen (eds) *Long Term Economic Development, Economic Complexity and Evolution*. Berlin, Springer-Verlag.

Boeri, T. and Jimeno, J. F. (2005) The effects of employment protection: learning from variable enforcement, European Economic Review, Elsevier, 49(8), 2057-2077..

Bottazzi, L. and Peri, G. (2007) The international dynamics of R&D and innovation in the long run and in the short run, *Economic Journal*, vol. 117, 486-511.

G. Bottazzi, G. Dosi, N. Jacobi, A. Secchi, F. Tamagni (2010) Corporate performances and market selection. Some comparative evidence. *Industrial And Corporate Change* 19(6): 1953-1996

Bugamelli, M., Cannari, L., Lotti, F., Magri, S. (2011) Il Gap Innovativo del sistema produttivo italiano: radici e posisbili rimedi. Banca d'Italia working paper

Castiglione, C. and Infante, D. (2013) 'ICT as general purpose technologies: a micro-econometric investigation on Italian firms', Int. J. Trade and Global Markets, Vol. 6, No. 3, pp.225–241.

Cantwell, J. (2002) Innovation, profits and growth: Penrose and Schumpeter. In C. Pitelis (ed.) *The theory of the growth of the firm: the legacy of Edith Penrose*. Oxford, Oxford University Press, 215-248.

Cefis, E. and Ciccarelli, M. (2005) Profit Differentials and Innovation, *Economics of Innovation and New Technologies*, vol. 14(1-2), 43-61.

Cincera, M. and Ravet, J. (2010) Financing constraints and R&D investments of large corporations in Europe and the USA, *IPTS Working Paper on Corporate R&D and Innovation*, 3/2010.

Cincera M. And Veugelers, R. (2010) Young Leading Innovators and EU's R&D intensity gap, IPTS Working Papers on Corporate R&D and Innovation, 2010-07.

Coad, A. and Rao, R. (2010) Firm growth and R&D Expenditure, *Economics of Innovation and New Technologies*, 19(2), 127-145

Cohen, W. M. And Levinthal, D. A., Innovation and learning: the two faces of R&D, The Economic Journal, 99, 569-596.

Crafts, N. and Mills, T. C. (2005) TFP growth in British and German manufacturing, 1950-1996, *Economic Journal*, vol. 115, 649-670.

Crépon, B., Duguet, E. and Mairesse, J. (1998) Research and development, innovation and productivity: an econometric analysis at the firm level, *Nber Working paper*, 6696.

Crespi, F. and Pianta, M. (2008) New processes and new products in Europe and Italy, *Rivista di Politica Economica*, 3-4: 119-148.

Dasgupta, P. and Stiglitz, J. (1980) Industrial structure and the nature of innovative activity, Economic Journal, 90, 226-293.

De Nardis, S., Pappalardo, C. (2011) Multi-Product Producers and Exporters: evidence for Italy. Mimeo

Dosi, G. (2007) Statistical regularities in the evolution of industries: a guide through some evidence and challenges for the theory in Malerba, F., Brusoni, s. (eds.): *Perspectives on innovation*, Cambridge, Cambridge University Press, 2007.

Dosi, G., R.R. Nelson (2010) Technical Change and Industrial Dynamics as Evolutionary Processes, Handbook of the Economics of Innovation; North-Holland, 51-128.

Dosi, G., Lechevalier, S., Secchi, A. (2010) Introduction: Interfirm heterogeneity: nature, sources and consequences for industrial dynamics, *Industrial and Corporate Change*; 19(6), 1867-1890.

Dosi, G., Grazzi M., Tomasi C., Zeli A., (2012) Turbulence underneath the big calm? The micro-evidence behind Italian productivity dynamics, *Small Business Economics*, May 2012.

Fagerberg, J., Mowery, D. and Nelson, R. (eds) (2005) *The Oxford Handbook of Innovation*, Oxford, Oxford University Press.

Geroski, P., Machin, S. and Van Reenen, J. (1993) The profitability of innovating firm, *RAND Journal of Economics*, vol. 24(2), 198-211.

Guarascio, D., Pianta, M. and Bogliacino, F. (2015) Export, R&D and New Products. A Model and a Test on European Industries. *Journal of Evolutionary Economics* (forth.).

Hall, B. H. (2002) The Financing of Research and Development, *Oxford Review of Economic Policy*, vol. 18(1), 35-51.

Hall, B. H., Lotti, F., Mairesse, J. (2009) Innovation and productivity in SMEs: empirical evidence for Italy, Small business Economics, Springer, 33(1), 13-33.

Hall, B. H., Lotti, F., Mairesse, J. (2012) Evidence on the impact of R&D and ICT investment on innovation and productivity in Italian firms, NBER working paper, 18053.

Kaldor, N. (1981) The role of increasing returns, technical progress and cumulative causation (Raffaele Mattioli Lectures), Cambridge University Press, Cambridge.

Kaldor, N. (1972) The irrelevance of equilibrium economics. Economic Journal, 82(328), 1237-1255

Kessler R.C., Greenberg D.F. (1981). Linear Panel Analysis: Models of quantitative Change, Academic Press.

Kleinkecht, A., Verspagen, B. 1990. Demand and innovation: Schmookler re-examined. Research Policy, 19:387-394

Klepper, S. (1997) Industry Life Cycles, *Industry and Corporate Change*, 6 (1), 145-181.

Lanjouw, J. O. and Schankerman, M. (2004) Patent quality and research productivity: measuring innovation with multiple indicators, *Economic Journal*, vol. 114, 441-465.

Mairesse, J. and Mohnen, P. (2002) Accounting for innovation and measuring innovativeness: an illustrative framework and an application. *American Economic Review, Papers and Proceedings*, 92(2), 226-230.

Mairesse, J., Mohnen, P. (2010) Using Innovations Surveys for Econometric Analysis, *NBER working paper*, w15857.

Milana C., Nascia L., Zeli., (2013) Decomposing multifactor productivity in Italy from 1998 to 2004: evidence from large firms and SMEs using DEA. Journal of Productivity Analysis, August 2013, Volume 40, Issue 1, pp 99-109

Mowery, DC., Rosenberg, N. 1979. The influence of market demand upon innovation: a critical review of some recent empirical studies. Research Policy, 8: 102-153

Nardecchia R., Sanzo R., Zeli A. (2010). La costruzione di un panel retrospettivo di micro-dati per le imprese italiane con 20 addetti ed oltre dal 1998 al 2004, Documenti Istat n.7, 2010.

Nardecchia R., Sanzo R., Zeli A. (2011). "Analisi dell'andamento della produttività delle imprese manifatturiere italiane tra il 1998 e il 2007 attraverso l'utilizzo di basi dati longitudinali" presented at the Istat workshop 'L'analisi dei dati di impresa per la conoscenza del sistema produttivo italiano: il ruolo della statistica ufficiale', 21-22 November 2011, Rome, Italy.

Oropallo S., Rossetti L., (2011). "Esportazioni e produttività: un'analisi panel sulle imprese manifatturiere italiane" presented at the Istat workshop 'L'analisi dei dati di impresa per la conoscenza del sistema produttivo italiano: il ruolo della statistica ufficiale', 21-22 November 2011, Rome, Italy

O'Sullivan, M. (2005) Finance and innovation, in J. Fagerberg, D. Mowery and R. Nelson (eds), 240-266.

Parisi, M. L., Schiantarelli, F. and Sembenelli, A. (2006) Productivity, Innovation and R&D: Micro evidence for Italy, *European Economic Review*, vol. 50:2037-2061.

Pellegrino, G., Piva, M., Vivarelli, M. (2012) Young firms and innovation: A microeconometric analysis, *Structural Change and Economic Dynamics*, 23(4): 329-340

Pianta, M. 2001. 'Innovation, demand and employment', in P. Petit and L. Soete (eds), *Technology and the future of European employment*, Elgar, Aldershot, 142-165.

Piva, M., Vivarelli, M. 2007. Is demand-pulled innovation equally important in different groups of firms? *Cambridge Journal of Economics*, 31: 691-710

Reinganum, J. F., (1983). Uncertain Innovation and the Persistence of Monopoly, American Economic Review, , 73(4), 741-48,

Ricardo, D. (1819) The Principles of Political Economy and Taxation, Cambridge University Press, Cambridge.

Schmookler, J. (1966) Invention and economic growth, Harvard University Press, Cambridge.

Schumpeter, J.A. (1955) *Theory of Economic Development*, Cambridge (Mass.), Harvard University Press (1st edn 1911).

Sylos Labini, P. (1984), Le forze dello sviluppo e del declino, Rome-Bari: Laterza.

Teece, D. (1986) Profiting from technological innovation. *Research Policy* 15(6), 285-305.

Tirole, J. 1988. The Theory of Industrial Organization. Cambridge, Massachusetts: Cambridge University Press

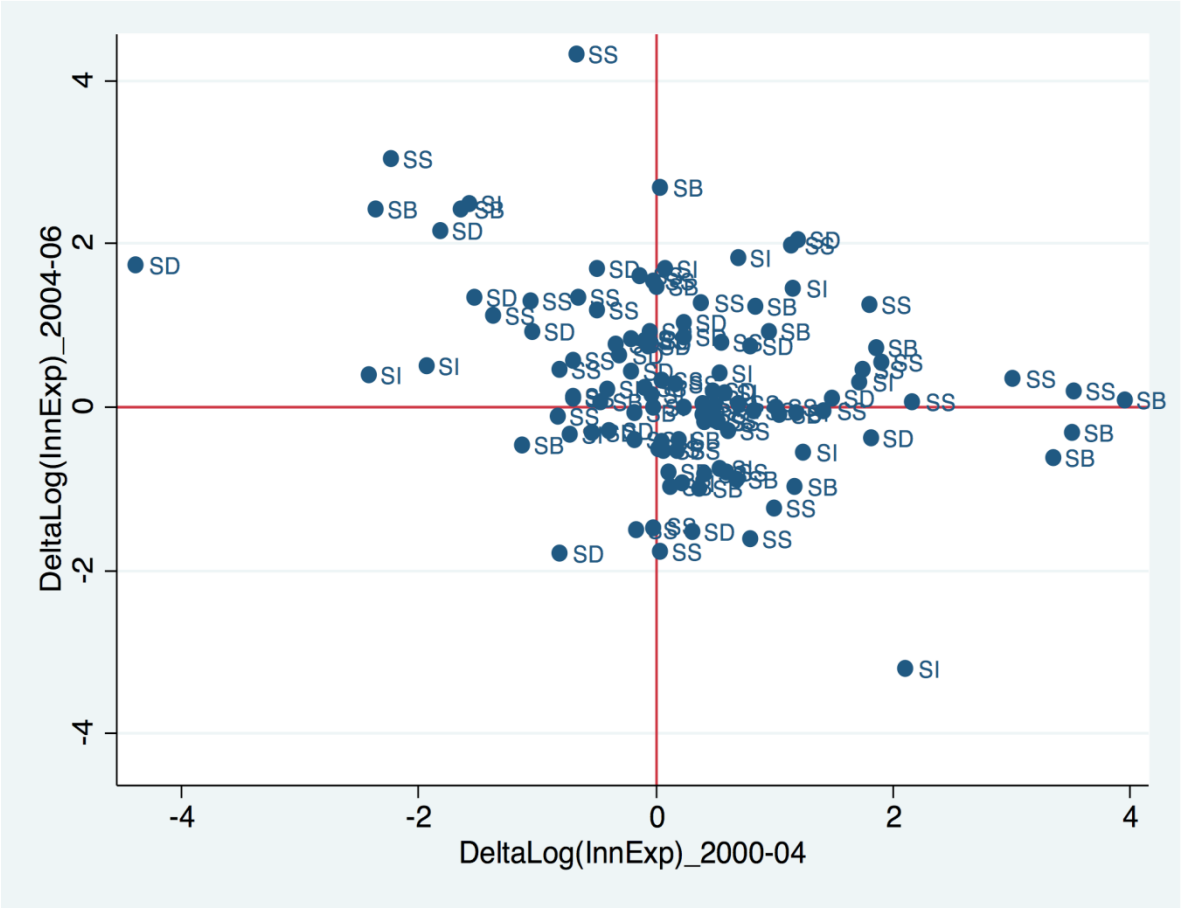
Velucchi M., Viviani A., Zeli A. (2011) "Determinants of the Italian Labor Productivity: A Quantile Regression Approach" presented at the Istat workshop 'L'analisi dei dati di impresa per la conoscenza del sistema produttivo italiano: il ruolo della statistica ufficiale', 21-22 November 2011, Rome, Italy

Wooldridge, J. M. (2002) *Econometric Analysis of Cross Section and Panel Data*. Cambridge: MIT Press.

Appendix

In Figure A1 we report the empirical evidence on the volatility of the distribution of change in innovative expenditure.

Figure A1. Change in innovative expenditure



We report in Table A1 the results of the additional estimation of our model that checks for the presence of omitted variables in the innovative expenditure equation, i.e. the influence of scale effects and market concentration on innovative expenditures. The role of scale in innovative activity and performance is an old issue, associated to the Schumpeterian Mark II model (Cohen and Levine, 1989). In their contribution, Crépon et al. (1998) run the estimation controlling for scale and stressing that it plays a large role in the equation for R&D. More recently, Parisi et al. (2006) run a similar system of three equations including a variable for scale in the R&D equation. In our estimation the variables have been already scaled by worked hours, but we further include the number of hours in the innovative expenditure equation.

Another debate from the standard Industrial Organization literature stresses the role of industrial structure and market concentration for the incentives to innovate. Game theoretical models show that there may exist two opposing effects. The first one is based on the lower cost to innovate that incumbents have, spurring them to introduce more innovation to preserve their market shares; in this case we would find a positive effect of concentration on innovative expenditure (Dasgupta and Stiglitz, 1980; Tirole, 1988). The second mechanism points out the incentive for new entrants to carry out greater innovative expenditure in order to replace incumbents; as new entrants are largely

excluded from our panel of serial innovators, in this case we would find a negative effect of concentration on innovative expenditure (Arrow, 1962; Reinganum, 1983). In order to test the relevance of such factors, we also add the Herfindhal index in the innovative expenditure equation.
When we use fixed effects estimators, we remove also the sectorally invariant (through time) characteristics. Results of the fixed effects estimator with size (hours) and concentration (Herfindal index) are reported in Table A1. The two variables come out not significant and the coefficients do no change, supporting the correctness of our specification.

Table A1. Control for size and industrial structure. Fixed effect estimation.

Dependent Variable	**Total turnover per hour**	**Innovative turnover per hour**	**Innovative expenditure per hour**
Total turnover per hour			0.03 (0.01)***
Innovative turnover per hour	0.16 (0.03)***		
Innovative expenditure per hour (first lag)		1.42 (0.85)*	-0.58 (0.07)***
Hourly wage	5.62 (1.07)***		
Hourly wage (first lag)			0.37 (0.16)**
Hourly productivity	1.32 (0.17)***		
Worked Hours			0.00 (0.00)
Export per hour		0.14 (0.08)*	
Herfindal index		-93.61 (18.37)***	0.46 (1.45)
R^2	0.43	0.11	0.26
Chi2	180.65***	31.44***	88.95***
No. Obs.	242	242	242

Source: Selection from ISTAT Panel of Italian Firms (all firms above 50 employees).
*, **, *** stands for significance at 10, 5 and 1 percent.