Innovation performances in Europe:
a long term perspective

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Abstract

In this paper, the long term mechanisms that are at the root of innovative activities and link innovation to economic performances are investigated in detail based on the three waves of the European Community Innovation Surveys (CIS 2, 3, 4).

The patterns of innovative activities, outcomes and performances are examined at the sectoral level, allowing to test the cumulative nature of technological change and the possible presence of lock-in effects in the trajectories of technological development of major EU countries. The long term patterns of innovative performances are examined with reference to both industries and countries.

In section 1 the approach and the data are presented. The database used is the Sectoral Innovation Database developed at the University of Urbino with data from national sources of the Fourth, Third and Second Community Innovation Surveys (2002-2004, 1998-2000, 1994-1996). Data are available at the two-digit NACE classification of 21 manufacturing and 17 service industries (covering all manufacturing and business services). Countries' coverage includes 7 major European Union countries – Germany, France, Italy, the Netherlands, Portugal, Spain, and the United Kingdom, and one country outside the EU, Norway - that represent more than eighty percent of the European Economy.

In section 2 the relevance of CIS variables for an analysis over time is examined. We use a wide range of statistical techniques - multiple and factorial ANOVA; Spearman, Kendall and linear correlations - in order to test the stability of the distributions of a large number of CIS variables. We investigate the sectoral profiles, country profiles and compare different CIS results, for each country and for the database as a whole. We conclude that CIS variables are appropriate for investigating the dynamics of innovation over time, as well as across industries and countries.

In section 3 we introduce the distinction - made by previous studies – between innovation strategies searching either for *technological competitiveness*, through knowledge generation, product innovation and expansion to new markets, or for *cost competitiveness*, through labour saving investment, flexibility and restructuring. These concepts are empirically tested by applying principal components analysis to a large number of variables from the SID database; we find that they are able to summarise the variety of technological activities. While such strategies may coexist in firms and industries, either one is likely to be dominant in the innovative efforts of each sector.

In section 4 we address the complexity of the relationships underlying the long term process of technological change and its economic impact. We propose three equations, explaining the relevance of R&D efforts, the innovative outcomes (innovative turnover) and economic performances (profit growth).

R&D per employee is explained by the cumulative nature of R&D, by the lagged growth of profits (providing the resources for funding R&D), by the distance from the

technological frontier in the industry (measured by the gap in labour productivity), by the average firm size and by the relevance of market-oriented innovation (measured by the share of firms aiming to open up new markets).

The share of innovation-related turnover is explained by efforts for improving technological competitiveness (proxied by R&D per employee) and for improving cost competitiveness through technology adoption (proxied by the relevance of suppliers of machinery and intermediate inputs in the sources of innovation), and by the growth of demand (proxied by the change in industry value added).

The growth of profits (operating surplus, in real terms) is explained by the relevance of lagged innovative sales (a measure of Schumpeterian profits), and by the growth of demand (a measure of market expansion, proxied by the change in industry value added). The three equations are tested separately, obtaining significant results.

In addition, we test the lag structure in these relationships, finding a significant influence of lagged profits on R&D efforts, of the cumulative effects of past R&D on current one, and of lagged innovative turnover on profits. We test the relevance of lags of different duration, finding that a three to four year lag is relevant .

In section 5 the three equations are considered in a system. We show that the growth of industries' profits is jointly driven by the "pull" effect of expanding demand and by the "push" effect of the success of lagged innovative sales. They, in turn, are supported by the parallel efforts searching for technological competitiveness – through R&D, and for cost competitiveness - through the adoption of new technologies. R&D activities are cumulative, supported by lagged profits, and more important the closer industries are to the technological frontier.
In addition, we carry out a separate test for manufacturing industries alone. The results show that limited differences exist between manufacturing and service sectors; in particular, we find that in manufacturing innovative sales are supported neither by growing demand, nor by technology adoption, while R&D efforts remain related to firm size. In consequence, this suggests that demand and technology adoption are more important for innovation in service sectors, while firm size is not relevant.

Our analysis provides a comprehensive and dynamic account of the complex process that over time links innovative activities and economic performance. The relevance of the two parallel strategies of technological and cost competitiveness, and the feedback loop between profits, R&D and innovative performance driven by technological competitiveness are the key novelties of this paper, highlighting crucial aspects of the nature, dynamics and effects of innovation.

This view on the innovation-performance link may contribute to redefine innovation policies at the EU and country level, considering three main implications from our findings: a) demand side factors have a significant influence on innovative and economic performances; b) R&D activities, efforts to enter new markets, decisions to adopt new technologies affect innovative and economic performances in different ways; c) the lags that we have identified mean that we cannot expect policies supporting R&D and innovation to have a visible economic impact for some years.

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1. Introduction and methodology

A long term perspective on innovation

Recent research on innovation has had to choose between the opportunity to carry out time series analyses using R&D or patent data, or the possibility to use a much richer set of innovation variables drawn from the European CIS survey with a cross sectional approach.

R&D and patents are indicators that have major limitations for understanding the complexity of innovation processes. A number of studies (Archibugi and Pianta, 1996, Smith, 2005) have assessed the strengths and weaknesses of different technology indicators, pointing out that R&D and patents are of limited relevance in the innovative activities of some manufacturing and most service sectors, resulting in a serious underestimation of the extent of innovative efforts in these industries. In empirical analyses, these data have the advantage of being available over long time series for firms, industries and countries.

On the other hand, innovation survey data - see the summary results in European Commission-Eurostat (2001, 2004, Eurostat, 2008) - make it possible to capture a much broader range of innovative efforts carried out in firms, including internal and external R&D expenditure; the acquisition of outside knowledge; internal design and engineering efforts associated to new products and processes; the acquisition of innovation-related machinery and equipment. and efforts associated to the marketing of new products. Moreover, innovation surveys provide rich evidence on the sources of knowledge, on the type of innovation introduced, on the economic impact of new products on sales, on the overall strategies pursued by firms in their technological activities, and on the obstacles found in this efforts, among others. In empirical analyses, these data are available for firms, industries and countries within each CIS wave. Comparisons between the three CIS surveys, however, have so far been limited for several reasons.

In this paper, we introduce a long term perspective on innovation survey data, using a rich sectoral database described below. This makes it possible to address some of the fundamental questions on the dynamics of innovation efforts and outcomes, and on links with economic performance.

The Sectoral Innovation Database

In order to explore the diversity of the trajectories of technological change and the impact of innovation on economic performance and employment, this paper makes extensive use of a major database recently developed at the University of Urbino - the "Sectoral Innovation Database (SID)". Such database includes most variables for the three comparable waves of the Community Innovation Survey (CIS 2, 3 and 4), and integrates innovation data with a large amount of statistical information on economic performance and employment at the same sectoral level, drawn from different sources. The countries' coverage of the database includes 8 major European countries – Germany, France, Italy, Norway, Netherlands, Portugal, Spain, and United Kingdom - that represent more than eighty percent of the European Economy. Data are available at two-digit NACE classification for both manufacturing and service industries. The full description of the sources and methodology followed for the construction of the database is provided in the SID Methodological Notes (University of Urbino, 2007).

The Sectoral Innovation Database has been developed by integrating data from the national sources of the Fourth, Third and Second Community Innovation Surveys (2002-2004, 1998-2000, 1994-1996). Variables that will be used include several dimensions of innovative activities, including R&D expenditures, total innovation expenditures, expenditures for new machinery, external technological acquisitions, patents, innovative turnover, product innovation, process innovation, the sources of information relevant to innovation and its objectives; the funding of innovation; the obstacles to innovation; the links with business strategies and organisational change.

The Sectoral Innovation Database has been constructed by the University of Urbino through cooperation agreements with national data providers - either national statistical institutes or research groups with access to CIS data and authorisation to exchange the data (CIS 2 and 3); CIS 4 data are available from Eurostat, except for the UK, whose data have been obtained from the national data provider. The assembling of the database has been carried out using common data protocols and statistical procedures on data integration and standardisation.

The selection of countries and sectors has been made in order to make sure that no confidentiality problems in the access to data would emerge (due to the policies on data release by national statistical institutes or to the low number of firms in a given sector of a given country). Data in the Sectoral innovation database are representative of the total population of firms. For each variable, firm level data have been weighted by the weighting factors provided by National Statistical Institutes in order to report survey data to the universe of firms. The database on innovation variables therefore provides information for the total population of firms. This is a necessary condition to link innovation to other industry economic data coming from other international sources, such as the OECD-STAN database.

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

Table 1. SID database: Industries included.

INDUSTRIES	NACE
MANUFACTURING	
Food, drink & tobacco	15-16
Textiles	17
Clothing	18
Leather and footwear	19
Wood & products of wood and cork	20
Pulp, paper & paper products	21
Printing & publishing	22
Mineral oil refining, coke & nuclear fuel	23
Chemicals	24
Rubber & plastics	25
Non-metallic mineral products	26
Basic metals	27
Fabricated metal products	28
Mechanical engineering	29
Office machinery	30
Manufacture of electrical machinery and apparatus n.e.c.	31
Manufacture of radio, television and communication equipment and apparatus	32
Manufacture of medical, precision and optical instruments, watches and clocks	33
Motor vehicles	34
Manufacture of other transport equipment	35
Furniture, miscellaneous manufacturing; recycling	36-37
SERVICES	
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	52
Hotels & catering	55
Inland transport	60
Water transport	61
Air transport	62
Supporting and auxiliary transport activities; activities of travel agencies	63
Communications	64
Financial intermediation, except insurance and pension funding	65
Insurance and pension funding, except compulsory social security	66
Activities auxiliary to financial intermediation	67
Real estate activities	70
Renting of machinery and equipment	71
Computer and related activities	72
Research and development	73
Other business activities	74

The main economic performance indicators that will be considered in this paper include: value added, employment, labour productivity. Building on such data, a number of variables - all expressed in euros, at constant prices - relevant for our study will be constructed, including information on absolute and relative levels, and growth rates.

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

The list of industries included is presented in Table 1.

The main innovation variables that will be used in the empirical analysis, drawn from the SID database, are listed in Table 2. There are mainly two types of variables: structural variables tend to present the share of firms in the sector performing various innovative activities and are expressed in percentage terms, while expenditure variables are expressed as thousands of euros per employee, deflated by GDP deflators provided by Eurostat (correction for PPP has been made for non-euro countries, such as UK and Norway).

Table 2. SID Database: Innovation Variables.

Variable Description	Unit
Share of firms introducing new products	%
Share of firms introducing new processes	%
Share of firms innovating with the aim to open new markets	%
Share of firms innovating with the aim to reduce labour cost	%
Share of firms introducing innovative machinery and equipment	%
Share of firms performing in house R&D	%
Share of innovative firms	%
Share of turnover from new or improved products	%
Share of firms applying for a patent	%
Share of firms defining suppliers of equipment as source of inn.	%
Share of firms defining clients as source of inn.	%
In House R&D expenditure per employee	Thousands euros/empl
Total R&D expenditure per employee	Thousands euros/empl
Expenditure on innovative machinery and equipment per empl.	Thousands euros/empl
Total Innovative Expenditure	Thousands euros/empl

The main economic variables that will be used in the empirical analysis, drawn from the SID database, are listed in Table 3. They include the rates of change in labour productivity, labour compensation, demand and other performance related variables.

Table 3 SID database: Economic Variables

Variable Description	Unit	Source
Compound rate of growth of Labour Productivity	annual rate of growth	STAN
Compound rate of growth of Employee	annual rate of growth	STAN
Compound rate of growth of Labour Compensation per Employee	annual rate of growth	STAN
Compound rate of growth of Value Added	annual rate of growth	STAN
Compound rate of growth of Operating Surplus	annual rate of growth	STAN

The major strength of the database is the high sectoral breakdown and the availability of information also on services, that now account for the large majority of EU employment and value added. This unique database has been gathered through the sharing of national sources and does not infringe in confidentiality issues. While such data do not cover all EU countries (being limited to seven of them and one country outside the EU), they are able to account for all the major countries and some of the smaller ones. The confidentiality restrictions on the access to industry data and the small number of firms that can be present in each industry in several smaller EU countries mean that efforts at extending the country coverage would lead to a large number of missing values and a distorted dataset. Moreover, the initial CIS 2 data are often incomplete or lack comparability for many of the countries that are not included in the database. Therefore, the database that will be used offers an appropriate trade off between the need to investigate a large number of EU countries and the need to cover a long time span, using reliable data with few missing values.

2. The stability of innovation variables in the long term

In order to investigate the long term mechanisms that are at the root of innovative activities and link to innovation to economic performances, the first challenge is to test whether the statistical information available, drawn from three waves of the European Community Innovation Surveys (CIS 2,3,4) has the characteristics of stability and reliability that are pre-requisites for robust empirical investigations.

In this section we will consider a large number of variables drawn from CIS data, that describe the different dimensions of innovative activities in European manufacturing and service industries.

First, we carry out an overall test on the stability of the distributions across waves, industries and countries. Second, we analyse whether the different CIS waves provide a consistent picture for the sectoral patterns of innovation in each of the countries considered. Third, we compare the innovative profiles of countries, in order to assess whether they are similar or different in their ranking of industries in terms of innovation indicators. Fourth, we test the stability over time of the innovation variables in the aggregate of the countries considered.

The tests are carried out using three different measures of correlation - Spearman rank correlation, Kendall rank correlation and Linear correlation. The variables that are considered are the following:

- R&D expenditure per employee
- Machinery expenditure per employee
- Share of firms aiming to reduce labour costs
- Share of firms aiming to open up new markets
- Share of firms indicating suppliers as sources of innovation
- Share of firms indicating clients as sources of innovation
- Total innovation expenditure per employee
- Share of firms applying for a patent
- Share of firms introducing new products
- Share of firms introducing new processes

The results for the first two variables (R&D expenditure per employee and machinery expenditure per employee) - that are able to capture two key dimensions of innovative efforts in firms - are presented in this section; the results for the other variables are shown in the Appendix, tables 1 to 8. The discussion of the stability of the innovation variables investigated is based on the overall evidence obtained.

The overall stability of distributions

In order to address the ability of CIS data in the SID database to describe the structural patterns of technological change in European countries, we first carried out a multiple ANOVA to check the relevance of CIS waves, industries (defined by the NACE classification), and countries in the distributions of a set of innovation variables. Basically, we test whether the distribution of the variables is different in the dimensions proposed.

The test examined the joint distribution of R&D expenditure, new machinery expenditure, share of firms applying for patents, total innovation expenditure, share of firms indicating suppliers as source of innovation, share of firms indicating clients as source of innovation, share of firms innovating to reduce labour cost, share of firms aiming to open up new markets, share of firms introducing new products, and share of firms introducing new processes along the three dimension of waves, industries and countries.

Table 4. Multiple ANOVA for a set of innovation variables.

Statistic	Value	F	p-value
Model			
Wilks' Lambda	0.00	9.16	0.0000
Pillai's Trace	4.03	7.24	0.0000
Lawley-Hotelling Trace	11.38	11.94	0.0000
Roy's Largest Root	4.36	46.77	0.0000

WAVE			
Wilks' Lambda	0.26	45.30	0.0000
Pillai's Trace	0.90	40.35	0.0000
Lawley-Hotelling Trace	2.09	50.53	0.0000
Roy's Largest Root	1.70	82.85	0.0000
INDUSTRY			
Wilks' Lambda	0.05	4.47	0.0000
Pillai's Trace	2.17	3.70	0.0000
Lawley-Hotelling Trace	4.38	5.71	0.0000
Roy's Largest Root	2.45	32.65	0.0000
COUNTRY			
Wilks' Lambda	0.06	23.60	0.0000
Pillai's Trace	1.90	18.26	0.0000
Lawley-Hotelling Trace	4.22	29.08	0.0000
Roy's Largest Root	2.35	115.41	0.0000
Number of observations: 540			

Table 4 confirms that all dimensions - time, industries and countries – matter in shaping the distribution of the variables considered (the F-test reject the hypothesis that distributions are not different through waves, countries and industries).

Variability is the result of structural factors related to industry specificities, specialization patterns specific to countries and time effects related to economic cycles or other macroeconomic conditions. In order to further explore this issue we move to a more detailed analysis of each variable to detect the source of variability in the distribution.
We carried out a factorial ANOVA on each innovation variable in order to decompose the variance in the three dimensions. We report the results for two variables of expenditure (R&D per employee and new machinery per employee) and show the findings for the other ones in the Appendix, tables 1 to 8.

Table 5. Factorial ANOVA of R&D expenditure per employee.

	Partial SS	F	p-value
Model	7580.10	15.08	0.0000
WAVE	51.31	2.35	0.0965
INDUSTRY	6254.52	15.47	0.0000
COUNTRY	1129.43	14.76	0.0000
Number of observations: 648 R-squared: 0.53			

Table 6. Factorial ANOVA of new machinery expenditure per employee.

	Partial SS	F	p-value
Model	1204.72	4.37	0.0000
WAVE	35.75	2.98	0.0515
INDUSTRY	713.17	3.21	0.0000
COUNTRY	395.72	9.42	0.0000
Number of observations: 631 R-squared: 0.25			

The above results show that the time dimension is not statistically significant at 5 percent for the two variables; the sectoral and country dimensions explain the largest part of the variance (as shown by the magnitude in the second column). Similar results are found in the Appendix, tables 1 to 8, for total innovation expenditure, while the other variables confirm the diversity of distributions over time. The cumulative and path-dependent nature of technological change limits the importance of short term cycle effects in shaping the pattern of innovative activities, and is particularly relevant for the expenditure variables that are the ones less dependent on survey design and on respondents' interpretation, and less subject to measurement error. These results also suggest that the evidence does not reject our claim that the CIS is a valid tool to address the long-term dynamics of innovation and its relation with economic performance. In order to further test the stability of individual variables, in the next sections we carry out an analysis across sectors, countries and waves.

Sectoral Profiles

The second step in the investigation is to analyse the stability over time of the distributions of innovation variables across industries within each country. Our understanding of technological change emphasises the cumulative and path-dependent nature of innovative efforts, and therefore we do not expect to find sudden major changes - over the period covered by CIS 2, 3 and 4 - in the ranking and intensities of innovative performances across industries in Europe. However, this does not mean that patterns never change; especially for small countries, or in industries with few firms, we may experience significant change in the values of some innovation variables as a result of entry or exit of firms, or limited structural change. Moreover, even short term economic cycles may affect variables that are affected by firms' expectations on the evolution of markets, such as the decisions to invest in new machinery and to introduce new products.
Therefore what we want to explore here is whether the variables show erratic distributions, or systematic differences that might be due to a lack of comparability of CIS surveys or to statistical problems, rather than to real economic changes.

The methods used include Spearman rank correlation, Kendall's Tau correlation[1] and linear correlation for each indicator among different waves, testing at 5% the absence of correlation. This helps us to analyze in depths the industry profile and its stability through time without the noise of country effects. We report results for R&D expenditure and new machinery expenditure. The results for the other variables can be found in the Appendix, tables 9 to 16. [2]

[1] Given the difficulties to interpret Spearman magnitude (it is not a purely monotonic measure), we include also Kendall rank correlation, whose meaning is straightforward.

[2] In the Appendix we report Spearman rank correlations only, for brevity. For this and the other tests, additional results are available upon request.

Table 7. Spearman Rank Correlation for R&D expenditure per employee

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.86*	0.96*	0.96*	0.89*	0.95*	0.87*	0.73*	0.90*
CIS 2-4	0.90*	0.96*	0.83*	0.88*	0.70*	0.77*	0.55*	0.89*
CIS 3-4	0.93*	0.98*	0.92*	0.96*	0.78*	0.65*	0.47*	0.92*

* significant at 5% level. "n.a." is written whenever data are not sufficient to compute it.

Source: SID database.

Table 8. Spearman Rank Correlation for machinery expenditure per employee

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.32	0.76*	n.a.	0.75*	0.38	0.51*	0.13	0.54*
CIS 2-4	0.09	0.35	n.a.	0.65*	0.74*	0.21	0.46*	0.22
CIS 3-4	0.84*	0.40	n.a.	0.61*	0.01	0.71*	0.28	0.42

* significant at 5% level. "n.a." is written whenever data are not sufficient to compute it.

Source: SID database.

Table 9. Kendall Rank Correlation for R&D expenditure per employee

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.71*	0.87*	0.86*	0.71*	0.86*	0.69*	0.56*	0.81*
CIS 2-4	0.76*	0.85*	0.69*	0.71*	0.64*	0.62*	0.36*	0.76*
CIS 3-4	0.83*	0.91*	0.78*	0.85*	0.68*	0.49*	0.35*	0.81*

* significant at 5% level. "n.a." is written whenever data are not sufficient to compute it.

Source: SID database.

Table 10. Kendall Rank Correlation for machinery expenditure per employee

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.23	0.60*	n.a.	0.50*	0.27	0.41*	0.09	0.42*
CIS 2-4	0.05	0.19	n.a.	0.56*	0.52*	0.19	0.35*	0.13
CIS 3-4	0.68*	0.27	n.a.	0.47*	0.01	0.56*	0.18	0.32

* significant at 5% level. "n.a." is written whenever data are not sufficient to compute it.

Source: SID database.

Table 11. Linear Correlation for R&D expenditure per employee

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.87*	0.98*	0.94*	0.87*	0.70*	0.88*	0.54*	0.89*
CIS 2-4	0.75*	0.80*	0.82*	0.94*	0.90*	0.78*	0.27	0.95*
CIS 3-4	0.94*	0.85*	0.78*	0.86*	0.89*	0.27*	0.07	0.94*

* significant at 5% level. "n.a." is written whenever data are not sufficient to compute it.

Source: SID database

Table 12. Linear Correlation for machinery expenditure per employee

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.01	0.74*	n.a.	0.65*	0.57*	0.54*	0.05	0.79*
CIS 2-4	0.05	0.16	0.51*	0.62*	0.65*	0.21	0.04	0.19
CIS 3-4	0.79*	0.55*	0.89	0.60*	0.78*	0.27	0.01	0.08

* significant at 5% level. "n.a." is written whenever data are not sufficient to compute it.

Source: SID database.

The different waves of CIS lead to results that show a general stability of the distributions of innovation variables within each country. Also, the three correlation measures provide in most cases coherent results.

In general, the R&D variable is more stable - and probably better understood by respondents - than the machinery expenditure variable. Only in the UK we find low linear correlation coefficients when CIS 4 is compared with the previous waves.

Data for machinery expenditure show weaker correlations in the case of the UK, Germany (when CIS 2 is concerned) and Norway (when CIS 4 is considered). The results shown in the Appendix (tables 9 to 16) for the other variables show similar strong consistency; only Portugal has weak correlations for several variables. While the UK has undergone a major process of structural change, Norway and Portugal are small countries with few firms in several industries.

These results show the strength of the CIS variables in the SID database as a tool for investigating the long term evolution of innovative activities in Europe.

Country profiles

How different are European countries in terms of the innovative activities carried out in their manufacturing and service industries?

A key question concerns the relevance of the sectoral specificities pointed out by the vast literature on industries' taxonomies (Pavitt, 1984), technological regimes (Breschi et al. 2000), and sectoral systems of innovations (Malerba 2004, 2005). According to this literature, industry patterns of innovation are shaped by fundamental characteristics of technological change, that are specific to the economic, social and knowledge-based context in which they develop.

But are industry specificities in innovation so strong that all countries end up with the same hierarchy of industries? Or, conversely, are country differences so strong that the relevance of innovation in the same industry can vary, depending on national factors?

In the following tables, we show Spearman, Kendall and Linear correlations for a battery of innovation variables. We proceed along the following steps: first, for all variables we calculate the mean (for CIS 2, 3, and 4) at industry level in each country; then we compute the rank correlation among different countries. In this way, we avoid disturbances due to time factors and concentrate on comparisons of long term country profiles across industries. Again we report the results for R&D and new machinery expenditure. Spearman correlations for the other variables can be found in the Appendix, tables 17 to 24.

The matrixes below provide the results of the comparisons of all the possible pairs of countries among the group of eight nations we consider in this study.

We use the following definition for countries: DE (Germany), ES (Spain), FR (France), IT (Italy), PT (Portugal), NL (the Netherlands), UK (United Kingdom), and NO (Norway).

Sectoral specificities appear much stronger than country specificities. This result confirms evidence from the literature. In general terms, only Portugal, due to its small size, has an innovation profile that is distinct from the larger EU countries.

However, when we investigate different variables, distinct national patterns emerge. On one hand variables associated to R&D and new products - that reflect a strategy of technological competitiveness - tend to show a more consistent picture among the large countries, suggesting that technological opportunities strongly constrain all countries that strive to innovate in products. On the other hand, variables linked to new machinery and new processes - that reflect a strategy of cost competitiveness - tend to reveal greater differences in the ranking shown by countries, suggesting that a wider range of options emerge for the countries that pursue different opportunities to "specialise" in different industries.

Table 13. Spearman Rank Correlation for R&D expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.92*	1.00						
FR	0.76*	0.86*	1.00					
IT	0.89*	0.91*	0.87*	1.00				
PT	0.44*	0.46*	0.48*	0.41*	1.00			
NL	0.77*	0.83*	0.74*	0.81*	0.47*	1.00		
UK	0.81*	0.85*	0.79*	0.88*	0.26*	0.83*	1.00	
NO	0.58*	0.66*	0.63*	0.53*	0.67*	0.64*	0.45*	1.00

* significant at 5% level.

Source: SID database.

Table 14. Spearman Rank Correlation for machinery expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.59*	1.00						
FR	0.32	0.50*	1.00					
IT	0.74*	0.86*	0.54*	1.00				
PT	0.11	0.47*	0.46*	0.34	1.00			
NL	0.52*	0.47*	0.50*	0.52*	0.41*	1.00		
UK	0.39*	0.05	0.16	0.28	0.02	0.28	1.00	
NO	0.49*	0.67*	0.38*	0.56*	0.47*	0.43*	0.28	1.00

* significant at 5% level.

Source: SID database.

Table 15. Kendall Rank Correlation for R&D expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.77*	1.00						
FR	0.59*	0.69*	1.00					
IT	0.73*	0.78*	0.71*	1.00				
PT	0.33*	0.36*	0.36*	0.31*	1.00			
NL	0.57*	0.63*	0.55*	0.62*	0.34*	1.00		
UK	0.61*	0.67*	0.60*	0.72*	0.20	0.66*	1.00	
NO	0.47*	0.53*	0.48*	0.42*	0.47*	0.46*	0.33*	1.00

* significant at 5% level.

Source: SID database.

Table 16. Kendall Rank Correlation for machinery expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.45*	1.00						
FR	0.27	0.37*	1.00					
IT	0.57*	0.68*	0.41*	1.00				
PT	0.05	0.35*	0.34*	0.28*	1.00			
NL	0.36*	0.32*	0.35*	0.38*	0.28*	1.00		
UK	0.31*	0.09	0.18	0.27*	0.07	0.23	1.00	
NO	0.36*	0.51*	0.29*	0.43*	0.34*	0.30*	0.23	1.00

* significant at 5% level.

Source: SID database.

Table 17. Linear Correlation for R&D expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.76*	1.00						
FR	0.85*	0.78*	1.00					
IT	0.94*	0.77*	0.70*	1.00				
PT	0.68*	0.45*	0.44*	0.71*	1.00			
NL	0.77*	0.69*	0.76*	0.81*	0.64*	1.00		
UK	0.84*	0.70*	0.74*	0.74*	0.62	0.73*	1.00	
NO	0.77*	0.73*	0.71*	0.47*	0.73*	0.87*	0.49*	1.00

* significant at 5% level.

Source: SID database.

Table 18. Linear Correlation for machinery expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.70*	1.00						
FR	0.27	0.22	1.00					
IT	0.56*	0.58*	0.17	1.00				
PT	0.35	0.72*	0.49*	0.20	1.00			
NL	0.32	0.48*	0.34	0.57*	0.50*	1.00		
UK	0.10	-0.06	0.28	0.02	0.28	0.09	1.00	
NO	0.48*	0.35	0.24	0.31	0.27	0.20	-0.03	1.00

* significant at 5% level.

Source: SID database.

Time patterns

How consistent are the pictures that emerge from the three CIS surveys? In this section we test the stability over time of the same variables, considering all countries together. We calculate the mean for each innovation variable at the industry level for the whole of Europe, but separately for CIS 2, CIS 3, and CIS 4. After that we compute the Spearman, Kendall and linear correlations. Results are shown in the Tables below.

Table 19. Spearman Rank Correlation for R&D expenditure per employee in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.95*	1.00	
CIS 4	0.95*	0.92*	1.00

* significant at 5% level.

Source: SID database.

Table 20. Spearman Rank Correlation for machinery expenditure per employee in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.91*	1.00	
CIS 4	0.61*	0.60*	1.00

* significant at 5% level.

Source: SID database.

Table 21. Kendall Rank Correlation for R&D expenditure per employee in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.85*	1.00	
CIS 4	0.82*	0.76*	1.00

* significant at 5% level.

Source: SID database.

Table 22. Kendall Rank Correlation for machinery expenditure per employee in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.75*	1.00	
CIS 4	0.49*	0.49*	1.00

* significant at 5% level.

Source: SID database.

Table 23. Linear Correlation for R&D expenditure per employee in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.95*	1.00	
CIS 4	0.94*	0.85*	1.00

* significant at 5% level.

Source: SID database.

Table 24. Linear Correlation for machinery expenditure per employee in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.77*	1.00	
CIS 4	0.68*	0.28	1.00

* significant at 5% level.

Source: SID database.

Again, a very strong stability emerges in most innovation variables. The three innovation surveys appear to provide a consistent picture of the relevance of innovation across the whole of Europe over time.

The stability is lower for the variable on machinery expenditure, which shows a weak linear correlation between CIS 3 (with data for 2000, a peak year of the business cycle) and CIS 4 (with data for 2004, a year of modest growth in Europe); the influence of cyclical factors has probably played a key role in this result.

Based on these results, we can argue that the three CIS surveys considered, and the SID database, provide a solid and stable picture of the complexity and variety of innovative activities in Europe. The comparisons over time have shown the stability of CIS variables and have identified the factors leading to changes in distributions.

The importance of industries - in both manufacturing and services - in shaping the characteristics and ranking of innovative activities has been confirmed. A greater diversity has been found in national patterns - in terms of sectoral specialization profiles - especially when variables reflecting the variety of possible technological strategies were considered.

3. A conceptualization of technological strategies

After showing the value of CIS data for a study of the long term patterns of innovation in Europe, we propose a conceptualisation of technological strategies that can help summarise the large body of evidence emerging from innovation survey variables.

The literature on innovation has often investigated the differences in the sources, nature and impact of technological change, leading to useful taxonomies [3] of firms and industries that tried to capture the fundamental features of innovation efforts. The Pavitt taxonomy (Pavitt, 1984) is perhaps the best known typology of innovative patterns and in related works (Bogliacino and Pianta, 2009) we have tested the strength of a Revised Pavitt taxonomy extended to services and ICTs.

In a large body of work, we have also documented the importance of the distinction between two fundamentally different technological strategies, searching either for *technological competitiveness*, based on knowledge generation, product innovation and expansion of new markets, or aiming at greater *cost competitiveness*, based on job reductions, labour saving investment, flexibility and restructuring.[4] Such strategies can be documented by the relevance of different innovation variables in the activities of firms and industries. The first one is related to strong R&D efforts and patent applications, widespread introduction of new products, high shares of turnover from new products, an aim to open new markets and the relevance of clients as sources of innovation. The second one is related to high machinery expenditures, widespread introduction of new processes, an aim to reduce labour costs and increase flexibility, the relevance of suppliers as sources of innovation.

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[3] See for instance Pavitt (1984), Tidd et al (2005), Breschi et al. (2001).

[4] For a definition see Pianta (2001). The empirical studies applying such a definition include Crespi and Pianta (2007, 2008a, b), Pianta (2006), Pianta and Tancioni (2008).

These strategies are dynamic patterns, which affect innovative performances, productivity growth and job creation and destruction in different ways; they may coexist inside the same firm of industry, but a relative prevalence of either strategy has usually been found in the empirical studies on this topic. Moreover, in Bogliacino and Pianta (2009b) we integrate this conceptualization into the Revised Pavitt Taxonomy, showing how these strategies display their effects in different ways in the Pavitt classes.

In a study of the long term patterns of innovation in Europe, we expect that these two major technological strategies will emerge as important explanatory factors. In this section, we carry out an empirical analysis on the database used, to test the robustness of the distinction between *technological and cost competitiveness*. We have considered the innovation variables listed in the previous section, pooling all industries, countries and CIS waves, and we have carried out a principal component analysis, where we try to isolate the latent factors that can explain the distributions of variables. Again, we have selected the variables – among all those available in CIS surveys - according to two criteria: on the one hand we look at their relevance (expenditure variables, innovation performance measures, objectives, sources), and on the other hand we choose variables whose reliability in terms of data was stronger (the ones with fewer missing values).

Table 25. Technological Competitiveness versus Cost Competitiveness.

Variable	Factor 1 Supplier-led Cost Compet.	Factor 2 New product Technol. Compet.	Factor 3 Science based Technol. Compet.	Factor 4 Machinery-based Cost Compet.	1-commonality
R&D expenditure per employee	0.06	0.13	0.88	0.29	0.10
New machinery expenditure per employee	0.06	0.12	0.18	0.96	0.02
Share of firms with product innovation	0.31	0.87	0.06	0.18	0.09
Share of firms with process innovation	0.46	0.74	0.34	0.08	0.09
Share of firms aiming to reduce labour costs	0.87	0.38	0.01	0.07	0.08
Share of firms aiming to open up new markets	0.84	0.44	0.18	0.06	0.04
Share of firms applying for a patent	0.44	0.49	0.60	-0.03	0.19
Share of firms indicating suppliers as source of innovation	0.96	0.06	0.05	0.02	0.07
Share of firms indicating clients as source of innovation	0.87	0.32	0.26	0.07	0.05
Share of turnover from new products	0.27	0.63	0.47	0.06	0.28

Method: Principal Component Analysis (retained eigenvalues are greater than 0.5).
Rotation method: orthogonal varimax (Horst off)
Number of observations: 440.
Number of parameters: 32.

Table 25 shows the results of the principal components analysis. We extracted the ones with a larger impact (eigenvalue greater than 0.5) and did not put restrictions on their number.

Four latent dimensions emerged and the one-commonality test[5] confirms the robustness of the exercise: no outside factors seems to be neglected. The four factors clearly reflect the distinction between the strategies of technological and cost competitiveness and have a strong relationship with the four Pavitt classes.

Factors 2 and 3 account for two dimensions of technological competitiveness - the role of R&D and patents (typical also of the "Science based" class in Pavitt's taxonomy), and the importance of product innovations (as well as turnover from new products and process innovations). The sources of knowledge and competences that are developed within the firm and the ability to turn them into new goods and services with market success are key elements of the strategy of technological competitiveness.

Factors 1 and 4 reflect two dimensions of cost competitiveness – the role of suppliers as sources of innovation (as well as the relevance of clients and of the aim of reducing labour costs) and the importance of the adoption of new machinery incorporating process innovations. The former identifies sources of innovation that are largely external to the firm and industry (closely related to the "Supplier dominated" Pavitt class), while the latter emphasises the role of technology embodied in machinery, usually introduced with labour saving aims.

These two elements appear to effectively characterise the strategy of cost competitiveness.

These results confirm the strength of the distinction between technological and cost competitiveness strategies and show that it is grounded in the empirical evidence provided by the CIS data. These concepts can therefore be effectively used in the investigation of long term patterns of innovation in Europe.

4. The long-term dynamics of research efforts, innovative outcomes and economic performances

The complexity of the relationships underlying the long-term process of technological change is investigated in this section focusing on three questions - the determinants of R&D efforts, of innovative outcomes (innovative turnover) and of economic performances (growth of profits).

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[5] This test is deemed to capture the eventuality that the analysis is not able to cover the variables properly: a high value means that the variable does not stand in any of the latent component.

The R&D-innovation-productivity link has been investigated by the approach proposed by Crepon, Duguet and Mairesse (1998) and by Parisi, Schiantarelli and Sembenelli (2006) [6]. This strand of literature tries to provide an explanation for the innovation process breaking it down into: a) the decision to carry out an expenditure effort; b) the relation between innovative input *and* output, c) the impact of innovation performance on economic performance (usually productivity). This perspective, however, tends to emphasise a linear sequence - from a to c - and is based on the conceptualisation of innovation as an undifferentiated process, with R&D expenditure as the main origin of innovative inputs.

In this paper we develop a more complex view of innovation, with a basic distinction between the strategies of technological and cost competitiveness, discussed in the previous section. In investigating the determinants of innovative efforts, outcomes and impacts on performances, we systematically consider the diversity of innovative activities, considering variables that can reflect the strategies of technological and cost competitiveness. In particular, we improve the current literature in the following aspects:

First, we do not model innovation as a pure R&D phenomenon, and we include both technological competitiveness and cost competitiveness factors, thus allowing a differentiation of innovative efforts across industries, in harmony with the evidence provided by Evolutionary and New Schumpeterian literature on the existence of alternative technological paradigms. [7]

Second, we introduce in the models a temporal structure, with the presence of cumulative and feedback effects. Profits are the outcome of innovative effort and the main driver of it, but influence also the innovative effort through the provision of financial resources. [8]

Third, we carry out the analysis at the industry level - thus taking into account the characteristics of technologies and economic structures - and we extend the analysis to services, using the SID database described in section 1.

In this section we present three models on the determinants of:

a) the growth of profits

b) the share of innovative turnover

c) R&D expenditure per employee

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[6] For a previous contribution, although with single equation structure see Geroski et al. (1993).

[7] Dosi (1982) and (1988); Pavitt (1984); Malerba (2002) and (2004); Freeman (1995).

[8] See Hall (2002), O'Sullivan (2006).

In the next section the three models are included in a system of equations in order to explore the simultaneous determinants of the variables and the feedback effects that may exist.

In order to estimate the system on the SID database, we use system Two-Stage-Least-Squares (2SLS from now on), which under mild assumptions allows the identification of the coefficients. It is well known [9] that system 2SLS is equivalent to 2SLS performed equation by equation. As it sometimes happens, there is a trade off between consistency and efficiency in choosing an estimator. Due to modest sample size (inevitable with industry level data), we solve the trade-off by relying on consistency instead of efficiency. In fact, with 2SLS we only have to care about the orthogonality inside each equation, without taking care of what is happening elsewhere in the system. [10] As a result, we can focus on the choice of instruments equation by equation in order to guarantee identification. This operation is carried out in the following three subsections, where the proper exogeneity tests are performed (together with multicollinearity and other standard diagnostical tests).

Moreover, since a major improvement of our analysis on the existing literature is the consideration of the temporal dimension, we discuss the choice of the proper lags equation by equation.

The question of the time structure deserves a further consideration. In fact we have to harmonize the CIS data, which are referred to a three-year period, with time lags of four years, with the STAN data that are annual. For this reason, we choose to use as reference year for our time index, the final year of the CIS wave [11], thus considering time lags of four years (1996, 2000, 2004). We attribute CIS data to the final year of each wave, and we take from the STAN data the corresponding values. However, to see the effect of the technological effort of 2004 we need to have data of 2008, but STAN is not updated to that year.

We proceed in the following way: all estimations are done on data on first (log-) difference in order to control for unobserved heterogeneity. Since data up to 2008 are not available, we will look for a transformation of first difference, which is not affecting the basic assumptions on the random errors and makes estimation possible with available data. If we divide for the time span of each temporal window, we are simply making a linear transformation, which does not alter the assumptions over the disturbance term. Practically we are replacing long run rate of change with average annual rate of change. This way we can stop at 2006 (the last year available). We directly calculate the average rate of change over 1996-1999 to cover the first time span; 2000-2003 for the second one;

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[9] See Wooldridge (2002) p 192.

[10] See Wooldridge (2002) p. 199.

[11] Several variables, including those on innovative expenditures, are referred explicitly to the final year of CIS surveys.

and 2003-2006 for the third one (the small readjustment of the time windows, i.e. instead of using 1996- 2000, 2000-2004, 2004-2006, is caused by the need to have sufficiently large time span).

The profits equation

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

$$\log(\pi_{ijt}) = \alpha_0 + \alpha_1 \log(d_{ijt}) + \alpha_2 \log(inn.perf_{ijt-1}) + \varepsilon_{ij} + u_{ijt} \quad (1)$$

where i stands for industry, j for country and t for time. As usual we are assuming that technology openly displays its effect with a time lag, in accordance with the Schumpeterian perspective. Once taken in difference (to eliminate the individual time invariant effect), we get:

$$\Delta \log(\pi_{ijt}) = \alpha_1 \Delta \log(d_{ijt}) + \alpha_2 \Delta \log(inn.perf_{ijt-1}) + \Delta u_{ijt} \quad (2)$$

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

$$rateOS_{ijt} = \alpha_1\, rateVA_{ijt} + \alpha_2\, \Delta INNturnover_{ijt-1} + \Delta u_{ijt} \quad (3)$$

where $rateOS_{ijt}$ is the compound annual rate of change in operating surplus from t-1 to t and $rateVA_{ijt}$ has a similar definition with regards to value added.

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

Once the fixed effect is eliminated, we still have to address the problem of uneven size grouped data, due to the industry dimension of the single observation. Grouping data of unequal size affects consistency of the OLS estimator, thus we have to introduce a weighting procedure, using Weighted Least Squares (WLS)[12]. On this baseline estimation, we carry out the basic diagnostics for identification. They can be found in the following

[12] The weights used are the numbers of employee, as standard procedure.

Table 26: a Breusch-Pagan test for heteroschedasticity (which is not rejected), a Variance Inflating Factors analysis for multicollinearity and an exogeneity test[13].

The results do not reject our formulation, and we have to estimate robust standard errors (the Breusch-Pagan rejected the null hypothesis of homoschedasticity). Explanatory variables are orthogonal to the error term, and multicollinearity is not an issue. We can maintain a WLS with robust standard errors.

Table 26. Identification of the profit equation.

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

We can now try to define the optimal lag for the first equation. We run the baseline formulation with the explanatory variables up to the second lag. As one can see from Table 27, it is only the contemporaneous period for demand and the first lag for innovative performance that have explanatory power in the equation.

Table 27. The lag structure of the profits equation.

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

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

	[4.23]***	[-0.46]
N.observations	230	74
R2	0.24	0.27
Dependent Variable: compound rate of growth of operating surplus. WLS with robust standard errors and weighted data (weights are the numbers of employee). t-stat in brackets. * significant at 10%, ** significant at 5%, *** significant at 1%.		

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

According to the evidence provided by the Table 27, the change in profits is explained by the effect of growing value added (a proxy of demand) and by the introduction of successful innovations (reflecting the evolution of technological competences, supply structures and market power). However, there is a fundamental difference between these two main determinants: while demand acts contemporaneously, technology needs more time to display its effect. This is coherent with the trial-and-error nature of technological change typical of the Schumpeterian framework.

The innovation performance equation

In order to derive our second equation, we need an explanation of innovative performance. Following a recent strand of literature in the Schumpeterian perspective (Pianta, 2001; Crespi and Pianta, 2008; Bogliacino and Pianta, 2008; Pianta and Tancioni, 2008; Vaona and Pianta, 2008), we consider the two alternative strategies searching for technological competitiveness and for cost competitiveness described in section 3. They are rooted in the original Schumpeterian distinction between product and process innovation, and they have been found to be associated with very different outcomes in terms of innovative and economic performances.

We basically refer to a Cobb-Douglas specification of technological capabilities, as a function of the R&D stock (internal innovative capabilities), the stock of external technological acquisition (in terms of machinery, equipment, intermediate products) and demand:

$$\log(INNCAP_{ijt}) = \beta_0 + \beta_1 \log(MACH - stock_{ijt}) + \beta_2 \log(R\&D - stock_{ijt}) + \beta_3 \log(d_{ijt}) + \upsilon_{ij} + v_{ijt} \qquad (4)$$

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

$$Inn.perf_{ijt} = \beta_1 \Delta \log(MACH - stock_{ijt}) + \beta_2 \Delta \log(R\&D - stock_{ijt}) + \beta_3 \Delta \log(d_{ijt}) + \Delta v_{ijt} \qquad (5)$$

thus we interpret the change in innovation capabilities as a measure of innovative performance. We proxy the rate of change in R&D stock with the flow of R&D, called *R&D* (we calculate the expenditure per employee since we are working with industry level data). In order to have a measure of technological acquisition, we use the share of firms who indicate suppliers as a source of innovation (SSUP) [14]. Finally we use again the annual rate of change of value added to measure the change in demand.

$$Inn.perf_{ijt} = \beta_1 SSUP_{ijt} + \beta_2 ex - R\&D_{ijt} + \beta_3 \, rateVA_{ijt} + \Delta v_{ijt} \quad (6)$$

We use INNturnover as a measure of innovative performance [15] and equation (6) represents the second one to be included in our system.

In this way, the share of innovation-related turnover is explained by supply-side efforts for improving technological competitiveness (proxied by R&D per employee) and for improving cost competitiveness (proxied by the relevance of suppliers of machinery and intermediate inputs in the sources of innovation), and by the growth of demand (proxied by the change in industry value added).

Again, we have to discuss the identification strategy, going through the same steps as above. However, we know from theoretical reasoning (and data confirm it) that R&D expenditure is endogenous. In fact it is autoregressive and path dependent.

Innovative capabilities are related to past and present R&D effort, and therefore we instrument it with its first lag, country dummies, a time trend, demand growth, a lag for demand growth, share of firms indicating suppliers as source of innovation, share of firms aiming to open up a new market and average size of firm.

For this reason, we test exogeneity of SSUP and demand growth only (the regression for the test is now a 2SLS with robust standard error and weighted data).

Table 28. Identification of the profit equation.

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

[14] The reason why we use this variable instead of the new machinery expenditure is that the empirical evidence of CIS data does not allow a clear distinction between the role played by new machinery as a labour saving engine and the one played in conjunction with design and improvement of products, especially in the new ICT industries. For further details, see Pianta and Bogliacino (2008).

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

t-statistics (Rate of change of VA)	-1.91
p-value	0.06

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

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

The results from table 29 show that instruments behave as expected. Our lag formulation is satisfied with regard to R&D (the first lag is not significant). There is a variance inflation problem when we use both SSUP and its first lag (the two become not significant); we cannot distinguish the two on the bases of empirical evidence. However, using the contemporaneous measure (given that identification test are positive) allows taking into account adoption of technology and appears theoretically stronger.

Table 29. The Innovation Performance equation.

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

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

The empirical evidence suggests that our formulation, allowing for both technological and cost competitiveness, is able to deepen the understanding of innovative performances beyond the linearity of the standard approach. The choice set of firms is not unique: alternative innovative effort can be possible, and display different economic effects.

The fact that R&D lags are not significant should not come as a surprise. As we see in the following subsection, R&D is an autoregressive path dependent process and the effects of the lags are captured by the contemporaneous term.

The R&D equation

Finally, moving from the formulation of Crepon et al. (1998) and Parisi et al (2006), we consider an equation for R&D expenditure. We formulate it in first differences to eliminate the fixed effects:

$$\Delta\log(R\&D-stock_{ijt}) = \gamma_1\Delta\log(R\&D-stock_{ijt-1}) + \gamma_2\Delta\log(\pi_{ijt-1}) +$$
$$+\gamma_3 EMAR_{ijt} + \gamma_4 OPP_{ijt} + \gamma_5 size_{ijt} + \Delta z_{ijt} \qquad (8)$$

The baseline equation describes change in R&D stock (proxied with the flow) as an autoregressive, path dependent process, which relies on internal financial resources, considering the difficulty to raise the necessary funds on the financial market, due to specificity of innovation risks (Hall, 2002). We enrich the model by adding the average firm size in the sector, in order to test the association between R&D efforts and large firm size postulated by an old Schumpeterian debate (for a discussion see Cohen et Levine, 1989); we also include a variable on the objective of innovations - the share of firms innovating to enter new markets (EMAR) [16] - in order to test whether such aims are further drivers of R&D efforts. Finally, we consider the available opportunities, i.e. the potential advances that technological trajectories permit [17], an important issue raised by evolutionary theory.

A proxy for opportunity is not easy to find: we choose to introduce a catching up variable, calculated as the percentage distance of industry labour productivity from the highest value for the same industry in the sample (i.e. among the eight European countries considered). The formal definition can be found in (9):

$$OPP_{i,j,t} = 100\frac{|LP_{i,j,t} - LP_{i,j\max,t}|}{LP_{i,j\max,t}}$$
$$i \in NACE, \quad j \in \{DE, ES, FR, IT, NL, PT, UK, NO\} \qquad (9)$$
$$j\max = \{\bar{j} \mid LP_{i,\bar{j},t} \geq LP_{i,j,t}, \quad \forall j\}$$

This catching up variable should be correctly interpreted: expressing the distance in labour productivity, it defines the space that simple investment decisions can cover,

16 It can be interpreted dynamically as a proxy for the expected rate of growth of demand.

17 Malerba (2002) and Breschi et al. (2001).

without recurring to science or more formalized innovative efforts expressed by R&D [18]. We discuss expected signs later, but in this case we expect a negative relationship with R&D intensities.

Reminding that we proxy the rate of change of R&D stock through the flow of expenditure per employee, as in equation (6), our estimated equation is as follows:

$$R\&D_{ijt} = \gamma_1 R\&D_{ijt-1} + \gamma_2 rateOS_{ijt-1} + \gamma_3 EMAR_{ijt} + \gamma_4 OPP_{ijt} + \gamma_5 size_{ijt} + \Delta z_{ijt} \quad (10)$$

In the last equation, the lag in R&D flow is endogenous with regards to the disturbance term, by construction (they both include z_{ijt-1}). We also treated as endogenous the catching-up variable being related to R&D because of learning mechanisms: R&D improves the capabilities of firms, making them discover new opportunities. The excluded instruments are: the rate of change of demand, the usual country dummies [19] and the lag of SSUP.

Our battery of tests for the identification is presented in Table 30. The estimation carried out for the exogeneity test is a weighted 2SLS with robust standard errors, with included endogenous and excluded instruments as discussed above. We limit the exogeneity test to the size variable (profits are lagged and EMAR conceptually cannot be endogenous).

Table 30. Identification of the R&D equation.

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

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

The basic formulation is not rejected by data. The results in Table 31 show that R&D efforts are cumulative (past R&D has an important role), they are supported by lagged profits (with one period lag), and are stronger where the space for catching up in labour

[18] It can be interpreted also as a competitive pressure to move the frontier; the larger the catching up space, the lower this pressure.

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

productivity is smaller. The firm size effect has a coefficient very close to zero and a negative sign, rejecting the traditional link between R&D and firm size; the role of new market objectives is not significant.

On the basis of this evidence, in the lag structure of the model we opt for the first lag for R&D and profits. We can now put together the three equations and estimate the system.

Table 31. The R&D equation.

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

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

5. The long-term interactions between research efforts, innovative outcomes and economic performances

In order to integrate the three models, to carry out a simultaneous estimation and to assess the feedback effects, we combine the three equations in the following system (11).

$$\begin{cases} rateOS_{ijt} = \alpha_1 rateVA_{ijt} + \alpha_2 \Delta INNturnover_{ijt-1} + \Delta u_{ijt} \\ INNturnover_{ijt} = \beta_1 SSUP_{ijt} + \beta_2 R\&D_{ijt} + \beta_3 rateVA_{ijt} + \Delta v_{ijt} \\ R\&D_{ijt} = \gamma_1 R\&D_{ijt-1} + \gamma_2 rateOS_{ijt-1} + \gamma_3 EMAR_{ijt} + \gamma_4 OPP_{ijt} + \gamma_5 size_{ijt} + \Delta z_{ijt} \end{cases} \quad (11)$$

The expected results are a straightforward implication of the theoretical background discussed above.

In the profit equation, we expect demand and lagged innovation performance to affect positively the dynamics of operating surplus.

In the innovation performance equation, we expect R&D to have a strong effect, capturing the search for technological competitiveness, associated to S&T advances and new products. We also expect the adoption of new technology through suppliers (SSUP) to have a positive effect. This can capture the effect of a cost competitiveness strategy, with the search for improved performances in industries. The role of demand is not obvious: on one hand it determines growth of turnover (which includes the innovative one), on the other hand it relaxes the competitive pressure to innovate, maintaining market share also for non innovators.

Finally, based on the R&D equation, we expect the process to be path dependent, with a strong impact of the lag of the dependent variable. R&D efforts are sustained by lagged profits that help finance internal innovative activities searching for technological advances. We argue that the pressure to undertake R&D may be inversely related to the distance of the industry from the frontier of productivity levels in the most efficient country. We define in this way a variable of opportunity, describing the space for growth of efficiency through investment and imitation, following the established technological trajectories. For technological leaders, undertaking R&D is the only way to advance efficiency and maintain competitiveness. We introduce the size variable in order to test the association between large firm size and high R&D, an hypothesis based on the Schumpeter Mark II model, emphasising the "deepening" pattern of technological change, in contrast to the "widening" pattern of Schumpeter Mark I models [20]. The sign of the variable will show the relative dominance of either model in European industries. Finally, the variable on the relevance of the objective to develop new markets may identify a specific market-pull effect on an industry's technological activities, that can be complementary to (but distinct from) R&D efforts in the search for technological competitiveness. We expect this variable to play a positive role.

The results

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

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[20] See Breschi et al. (2001). The widening pattern expresses the technological trajectories where entry and creative destruction are dominant processes, while the deepening patterns express sectors where cumulativeness and barriers to entry – and therefore large firm size - are important.

Table 32. The R&D equation.

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

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

Table 33. The Innovation Performance equation.

	(1) Overall Sample	(2) Manufacturing
R&D expenditure per employee	2.20	1.96
	[3.27]***	[2.98]***
Technology adoption	0.13	0.07
	[2.62]***	[1.21]
Rate of change of value added	0.11	-0.72
	[0.61]	[2.88]***
Constant	8.20	9.32
	[7.09]***	[5.86]***
N obs	145	100
Uncentered R2	0.74	0.78
Overidentification Test (Hansen J statistic)	14.19	20.74
p-value	0.07	0.00
First Stage Diagnostics		
Model F-Test (R&D)	5.80	5.56

p-value	0.0000	0.0000

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

Table 34. The profits equation

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

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

The results confirm our expectations, showing the strength of our model and the robustness of our estimations.

In the profits equations, both demand growth and lagged innovative performance have positive and significant coefficients. The results for manufacturing industries alone are very close to those on the overall sample.

In the innovative performance equation, both technological competitiveness (associated to R&D) and cost competitiveness (associated to technology adoption from external suppliers) positively contribute to the innovative turnover. Demand growth (proxied by value added) turns out to be non significant, as a result of the contrasting effects it may have, either "pulling" a higher innovative turnover, or allowing for higher sales with no need for innovation (for instance where strong market power exists). In the case of manufacturing industries, the latter effect becomes significant. Moreover, technology adoption loses its significance, as only reliance on suppliers can be inadequate for achieving a greater innovative turnover. In manufacturing, the dominant effect of technology adoption (of new machinery in particular) has been rather the reduction of labour use associated to widespread processes of restructuring (see Bogliacino and Pianta 2009a).

Finally, in the R&D equation, there are three important results. First, we confirm empirically the feedback effect of economic performance on R&D; the lag of profits is significant both in overall sample and manufacturing. Second, we confirm the path-dependent nature of technological competitiveness and R&D activities. We find a strong first lag effect for R&D efforts. Third, the pressure for carrying out R&D is stronger the closer the industry is to the technological frontier. The variable on opportunity is negative and significant. All three results are found for both the overall sample and for manufacturing alone. The effect of firm size on R&D is not significant for the overall sample and is modestly relevant for manufacturing. The aim to develop new markets is never significant. The lagged R&D variable appears to capture all the dimensions of industries' search for technological competitiveness.

Major strengths of our results are the integration of the three equations and the careful consideration of lags and feedback mechanisms, shedding light on the complex ways innovation activities and economic performances interact in European industries. Our findings show that the growth of industries' profits is jointly driven by the "pull" effect of expanding demand and value added, and by the "push" effect of the success of lagged innovation performances. They, in turn, are supported by the parallel efforts of searching for technological competitiveness - through R&D - and for cost competitiveness - through the adoption of new technologies (embodied in new machinery and intermediate inputs) from a range of external suppliers. While both strategies can be pursued in parallel, industries are characterised by a dominance of either pattern of competitiveness. Therefore, an explicit consideration of both mechanisms is needed in order to explain innovation performances across industries.

Finally, R&D activities are cumulative and path-dependent. They are supported by lagged profits, and they are higher when industries are closer to the technological frontier. The evolution of European manufacturing and service industries suggests that the traditional expectation of a link between firm size and R&D is rejected.

This summary of the relationships that are identified in our analysis provides a picture of a more complex process that links innovative activities and economic performances over time. The relevance of the two parallel strategies of technological and cost competitiveness, and the feedback loop between profits, R&D and innovative performances driven by technological competitiveness are the key novelties of this paper, highlighting crucial aspects of the nature, dynamics and effects of innovation.

A systematic comparison between the results for manufacturing and services and those for manufacturing industries alone is also interesting. In general, we confirm the findings of a broad range of previous studies (Crespi and Pianta, 2008a,b; Pianta and Tancioni, 2008; Bogliacino and Pianta 2009a,b), showing that little difference exists between the patterns of manufacturing and services, once the complexity and variety of technological activities is considered. We find that no difference exists in the determinants of profits. Innovative sales in manufacturing are "pushed" by R&D efforts and not "pulled" by growing demand, while the cost competitiveness strategies based on technology adoption are likely to lead to lower employment rather than to higher innovative turnover. In manufacturing R&D efforts - that in some service sectors are modest - are shaped by the cumulative nature of R&D, by lagged profits and by the need to advance the technological frontier in the same way as in the total sample. The only difference is that the relevance of firm size emerges in manufacturing only, where the Schumpeter Mark II model may still play an important role.

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

6. Conclusions

This paper investigates the long term relationships between innovation and performance: we first propose an original conceptual approach; second, we carry out extensive tests for the robustness of our concepts and data; and finally, we develop a model that can simultaneously explain, in a three equation system, the determinants of R&D, innovative performances and profit growth in manufacturing and service industries in eight major European countries. Our main findings can be summarised as follows:

a. CIS surveys provide a strong base for investigating the long-term patterns of innovation at industry and country levels. Key variables - described in section 1 - are stable over time and account for differences across industries and countries, showing a coherent pattern across subsequent CIS surveys - as shown in the detailed tests carried out in section 2. CIS variables - and the SID database we used – appear to be appropriate for investigating the dynamics of innovation over time, as well as across industries and countries.

b. In the long term, industry specificities appear to be stronger than country patterns in shaping the hierarchy of innovative activities across manufacturing and service sectors - as shown in section 2. This confirms the arguments of a large literature, and lends further importance to analyses carried out at the sectoral level, as in this paper.

c. The relevance of the distinction between the strategies of technological and cost competitiveness is documented by the analysis in section 3, using a large set of innovation variables. These concepts are an effective way to summarise the variety of technological activities. Such strategies may coexist in firms and industries, but the literature has identified the prevalence of either one in particular industries. In this paper we show that long term similarities across countries and over time tend to be stronger in the variables reflecting technological competitiveness (such as R&D efforts and product innovations) and relatively weaker in the variables accounting for cost competitiveness (such as expenditure for new machinery and process innovations), as a result of different patterns of specialisation, cyclical factors, etc.

d. The complexity of the relationships underlying the long term process of technological change and its economic impact is modelled - in section 4 - in three equations, explaining the relevance of R&D efforts, the innovative outcomes (innovative turnover) and economic performances (profit growth). Our models can be summarised as follows.

R&D per employee is explained by the cumulative nature of R&D, by the lagged growth of profits (providing the resources for funding R&D), by the distance from the technological frontier in the industry, by the average firm size and by the relevance of innovative strategies aiming to open up new markets.

The share of innovation-related turnover is explained by efforts for improving technological competitiveness (proxied by R&D per employee) and for improving cost competitiveness through technology adoption (proxied by the relevance of suppliers of machinery and intermediate inputs in the sources of innovation), and by the growth of demand (proxied by the change in industry value added).

The growth of profits (operating surplus, in real terms) is explained by the relevance of lagged innovative sales, and by the growth of demand.

The three equations have been tested separately, obtaining significant results, with coefficients having the expected sign. These models appear to effectively account for the major dimensions of the process of technological change and its economic effects.

e. There is a clear lag between factors influencing knowledge, technological activities and economic performances. We have explored in detail the lag structure of our relationships - in section 4 - and we have found a significant influence of lagged profits on R&D efforts, of the cumulative effects of past R&D on current one, and the effect of lagged innovative turnover on profits. We have tested the relevance of lags of different duration, finding that the three to four year lag is the most relevant one.

f. When the three equations, with the appropriate lags, are considered in a system – in section 5 - they are able to account in an effective way for the dynamics of innovation and economic performance of major European countries for the period from the mid 1990s to the present. The analysis is carried out over data for 38 industries, eight countries and two time periods (including lagged variables). The results are significant and convincing.

The growth of profit is explained by both demand growth and lagged innovative performance. The innovative performance is shaped by both technological competitiveness (associated to R&D) and cost competitiveness (associated to technology adoption from external suppliers), while demand growth is not significant.

R&D efforts are the result of cumulative research activities (lagged R&D), lagged profits and the pressure for carrying out R&D when industries are closer to the technological frontier. Firm size has an effect in manufacturing only and the aim to develop new markets is never significant.

g. The results for manufacturing and services and those for manufacturing industries alone have limited differences. Innovation performances in manufacturing are "pushed" by R&D efforts and not "pulled" by growing demand, while the cost competitiveness strategies based on technology adoption are likely to lead to lower employment rather than to higher innovative turnover. In manufacturing R&D efforts appear to be (moderately) related to firm size.
The main differences between manufacturing and services can therefore be summed up as follows: in service industries innovative sales are affected by technology adoption (and perhaps by demand growth), while this is not found in manufacturing; larger firms have greater R&D efforts in manufacturing (and not in services).

To our knowledge, it is the first time that such analytical approach is adopted and applied to innovation data. Our system of equations allows us to consider all the lagged effects and feed back mechanisms between profits, R&D efforts and innovative outcomes. The data used allow us to capture industry variety, country specificities and dynamics over time. Our findings provide one of the most comprehensive explanations of the long term patterns of innovation and performance available. We show that the growth of industries' profits is jointly driven by the "pull" effect of expanding demand and by the "push" effect of the success of lagged innovation performances. They, in turn, are supported by the parallel efforts searching for technological competitiveness - through R&D - and for cost competitiveness - through the adoption of new technologies. R&D activities are cumulative, supported by lagged profits, and more important the closer industries are at the technological frontier.

This paper has highlighted key mechanisms in the long term dynamics of technological and economic progress. The following three policy considerations emerge from our results:

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

2) Our findings have documented the diversity in the nature of innovation and technological strategies across industries. Innovation policies may consider that R&D activities, efforts to enter new markets, decisions to adopt new processes and technologies affect innovative and economic performances in different ways, and that their potential impact may differ across industries.

3) The lags that we have identified - between greater innovative turnover and improved economic performance and profits, and between higher profits and greater R&D efforts -

mean that we cannot expect policies supporting R&D and innovation to have a visible economic impact for some years.

The identification of specific relationships that are relevant for European countries may open the way to more detailed investigations of the policy tools that can be effective in influencing the pace and direction of technological change and in sustaining economic growth.

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Appendix

In this appendix we include the additional results that integrate the evidence discussed in the paper. In the text reference is made to these results whenever it is appropriate.

Table 35. Factorial ANOVA of share of firms innovating to reduce labour cost.

	Partial SS	F	p-value
Model	147347.59	22.64	0.0000
WAVE	63819.05	225.50	0.0000
INDUSTRY	35820.01	6.84	0.0000
COUNTRY	39910.60	40.29	0.0000

Number of observations: 736
R-squared: 0.60

Table 3628. Factorial ANOVA of share of firms innovating to open up new markets.

	Partial SS	F	p-value
Model	240979.339	34.29	0.0000
WAVE	77358.56	253.17	0.0000
INDUSTRY	72743.76	12.87	0.0000
COUNTRY	75697.55	70.78	0.0000

Number of observations: 741
R-squared: 0.69

Table 37. Factorial ANOVA of share of firms indicating suppliers as source of innovation.

	Partial SS	F	p-value
Model	122927.43	21.68	0.0000
WAVE	27356.39	110.98	0.0000
INDUSTRY	20315.84	4.45	0.0000
COUNTRY	75062.90	87.00	0.0000

Number of observations: 733
R-squared: 0.59

Table 38. Factorial ANOVA of share of firms indicating clients as source of innovation

	Partial SS	F	p-value
Model	223839.01	35.50	0.0000
WAVE	32508.58	118.59	0.0000
INDUSTRY	73749.65	14.54	0.0000
COUNTRY	107985.83	112.55	0.0000

Number of observations: 738
R-squared: 0.70

Table 39. Factorial ANOVA of total innovation expenditure per employee

	Partial SS	F	p-value
Model	13134.89	11.46	0.0000
WAVE	30.75	0.62	0.5398
INDUSTRY	11536.40	12.51	0.0000
COUNTRY	1321.06	7.57	0.0000

Number of observations: 634
R-squared: 0.47

Table 40. Factorial ANOVA of share of firms applying for patents.

	Partial SS	F	p-value
Model	61048.03	24.72	0.0000
INDUSTRY	43444.95	21.87	0.0000
COUNTRY	14225.73	37.85	0.0000
WAVE	1328.35	12.37	0.0000

Number of observations: 681
R-squared: 0.64

Table 41. Factorial ANOVA of share of firms introducing new processes.

	Partial SS	F	p-value
Model	87957.70	15.24	0.0000
INDUSTRY	47879.46	10.31	0.0000
COUNTRY	21215.30	24.15	0.0000
WAVE	11549.36	46.01	0.0000

Number of observations: 678
R-squared: 0.52

Table 4229. Factorial ANOVA of share of firms introducing new products.

	Partial SS	F	p-value
Model	192049.76	32.41	0.0000
WAVE	11755.68	45.63	0.0000
INDUSTRY	116791.15	24.51	0.0000
COUNTRY	46246.03	51.29	0.0000

Number of observations: 680
R-squared: 0.70

Table 43. Spearman Rank Correlation for share of firms in the industry aiming to reduce labour cost through innovation.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.56*	n.a.	0.71*	0.68*	0.74*	0.01	0.53*	0.78*
CIS 2-4	0.44*	n.a.	0.52*	0.66*	0.60*	0.41	0.61*	0.49*
CIS 3-4	0.03	n.a.	0.66*	0.77*	0.76*	-0.05	0.71*	0.48*

Table 44. Spearman Rank Correlation for share of firms in the industry aiming to open up new markets through innovation.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.44*	n.a.	0.64*	0.77*	0.90*	0.20	0.60*	0.78*
CIS 2-4	0.38*	n.a.	0.75*	0.69*	0.66*	0.06	0.56*	0.62*
CIS 3-4	0.56*	n.a.	0.58*	0.81*	0.58*	0.16	0.67*	0.49*

Table 45. Spearman Rank Correlation for share of firms in the industry indicating suppliers as the source of innovation.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	-0.18	n.a.	0.57*	-0.05	0.17	-0.03	0.41*	0.59*
CIS 2-4	0.25	n.a.	0.21	0.06	0.54*	0.00	0.30	0.49*
CIS 3-4	0.42*	n.a.	0.18	0.45*	0.71*	0.35	0.60*	0.42*

Table 306. Spearman Rank Correlation for share of firms in the industry indicating clients as the source of innovation.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.48*	n.a.	0.78*	0.66*	0.91*	0.15	0.80*	0.77*
CIS 2-4	0.54*	n.a.	0.84*	0.80*	0.74*	-0.08	0.66*	0.76*
CIS 3-4	0.65*	n.a.	0.72*	0.72*	0.88*	0.50*	0.62*	0.88*

Table 317. Spearman Rank Correlation total innovation expenditure per employee.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	n.a	0.94*	0.94*	0.92*	0.82*	0.75*	0.36	0.71*
CIS 2-4	n.a	0.93*	0.91*	0.89*	0.85*	0.43	0.44	0.85*
CIS 3-4	n.a.	0.88*	0.93*	0.90*	0.86*	0.70*	0.24	0.88*

Table 48. Spearman Rank Correlation for share of firms in the industry applying for a patent.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.82*	n.a.	0.87*	0.93*	0.94*	-0.07	0.84*	0.87*
CIS 2-4	0.73*	n.a.	0.73*	0.87*	0.88*	0.15	0.85*	0.87*
CIS 3-4	0.60*	n.a.	0.84*	0.91*	0.87*	0.02	0.90*	0.93*

Table 329. Spearman Rank Correlation for share of firms in the industry introducing new products.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.72*	0.91*	0.93*	0.87*	0.90*	0.55*	0.70*	0.85*
CIS 2-4	0.64*	0.85*	0.90*	0.81*	0.68*	0.70*	0.82*	0.74*
CIS 3-4	0.59*	0.80*	0.83*	0.81*	0.84*	0.55*	0.78*	0.74*

Table 50. Spearman Rank Correlation for share of firms in the industry introducing new processes.

	Germany	Spain	France	Italy	Netherlands	Portugal	UK	Norway
CIS 2-3	0.32	0.74*	0.73*	0.15	0.85*	0.10	0.79*	0.67*
CIS 2-4	0.29	0.53*	0.70*	0.55*	0.54	0.46*	0.54*	0.54*
CIS 3-4	0.52*	0.55*	0.70*	0.40	0.64*	0.35	0.41	0.76*

Table 51. Spearman Rank Correlation for share of firms in the industry indicating suppliers as the source of innovation in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.12	1.00						
FR	0.25	0.48*	1.00					
IT	0.28	0.41*	0.40*	1.00				
PT	0.12	0.14	0.31	0.23	1.00			
NL	0.32	0.18	0.38*	0.12	0.13	1.00		
UK	0.50*	0.45*	0.57*	0.46*	0.28	0.42*	1.00	
NO	0.45*	-0.11	0.43*	0.25	0.22	0.49*	0.51*	1.00

* significant at 5% level..

Source: SID database

Table 52. Spearman Rank Correlation for share of firms in the industry indicating clients as the source of innovation in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.64*	1.00						
FR	0.79*	0.77*	1.00					
IT	0.76*	0.79*	0.87*	1.00				
PT	0.46*	0.30	0.43*	0.37*	1.00			
NL	0.84*	0.74*	0.88*	0.83*	0.40*	1.00		
UK	0.80*	0.47*	0.76*	0.58*	0.48*	0.71*	1.00	
NO	0.78*	0.54*	0.79*	0.70*	0.39*	0.87*	0.72*	1.00

* significant at 5% level.

Source: SID database.

Table 53. Spearman Rank Correlation for share of firms in the industry introducing new products in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.86*	1.00						
FR	0.73*	0.82*	1.00					
IT	0.82*	0.88*	0.86*	1.00				
PT	0.62*	0.69*	0.59*	0.59*	1.00			
NL	0.71*	0.73*	0.83*	0.71*	0.35*	1.00		
UK	0.78*	0.70*	0.79*	0.71*	0.57*	0.80*	1.00	
NO	0.74*	0.74*	0.83*	0.76*	0.54*	0.80*	0.81*	1.00

* significant at 5% level.

Source: SID database.

Table 54. Spearman Rank Correlation for share of firms in the industry introducing new processes in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.57*	1.00						
FR	0.56*	0.80*	1.00					
IT	0.77*	0.59*	0.57*	1.00				
PT	0.26	0.52*	0.53*	0.20	1.00			
NL	0.57*	0.39*	0.41*	0.59*	-0.13	1.00		
UK	0.59*	0.47*	0.49*	0.67*	0.02	0.58*	1.00	
NO	0.44*	0.47*	0.58*	0.56*	0.17	0.68*	0.58*	1.00

* significant at 5% level.
Source: SID database.

Table 55. Spearman Rank Correlation for share of firms in the industry applying for a patent in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.80*	1.00						
FR	0.86*	0.87*	1.00					
IT	0.80*	0.88*	0.89*	1.00				
PT	0.54*	0.66*	0.66*	0.69*	1.00			
NL	0.82*	0.87*	0.94*	0.93*	0.62*	1.00		
UK	0.68*	0.58*	0.65*	0.61*	0.59*	0.67*	1.00	
NO	0.83*	0.82*	0.91*	0.80*	0.69*	0.83*	0.64*	1.00

* significant at 5% level.
Source: SID database.

Table 56. Spearman Rank Correlation total innovation expenditure per employee in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.74*	1.00						
FR	0.67*	0.85*	1.00					
IT	0.75*	0.88*	0.75*	1.00				
PT	0.12	0.37	0.41*	0.30	1.00			
NL	0.71*	0.75*	0.81*	0.75*	0.32	1.00		
UK	0.53*	0.33	0.41*	0.40*	-0.07	0.64*	1.00	
NO	0.54*	0.62*	0.58*	0.49*	0.37	0.64*	0.48*	1.00

* significant at 5% level.
Source: SID database.

Table 337. Spearman Rank Correlation for share of firms in the industry aiming to reduce labour cost through innovation in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.43*	1.00						
FR	0.56*	0.59*	1.00					
IT	0.43*	0.52*	0.75*	1.00				
PT	0.07	0.05	0.28	0.20	1.00			
NL	0.16	0.34	0.48*	0.49*	0.26	1.00		
UK	0.52*	0.47*	0.83*	0.66*	0.29	0.55*	1.00	
NO	0.46*	0.36*	0.78*	0.64*	0.33	0.50*	0.84*	1.00

* significant at 5% level.
Source: SID database.

Table 58. Spearman Rank Correlation for share of firms in the industry aiming to open up new markets through innovation in different European countries.

	DE	ES	FR	IT	PT	NL	UK	NO
DE	1.00							
ES	0.79*	1.00						
FR	0.63*	0.69*	1.00					
IT	0.60*	0.68*	0.78*	1.00				
PT	0.06	0.15	0.30	0.24	1.00			
NL	0.42*	0.51*	0.80*	0.73*	0.17	1.00		
UK	0.68*	0.81*	0.85*	0.81*	0.30	0.81*	1.00	
NO	0.40*	0.45*	0.76*	0.70*	0.29	0.86*	0.68*	1.00

* significant at 5% level.
Source: SID database.

Table 349. Spearman Rank Correlation for share of firms in the industry indicating suppliers as the source of innovation in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.63*	1.00	
CIS 4	0.43*	0.53*	1.00

* significant at 5% level.
Source: SID database.

Table 60. Spearman Rank Correlation for share of firms in the industry indicating clients as the source of innovation in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.90*	1.00	
CIS 4	0.69*	0.81*	1.00

* significant at 5% level.
Source: SID database.

Table 61. Spearman Rank Correlation for share of firms in the industry introducing new products in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.92*	1.00	
CIS 4	0.87*	0.93*	1.00

* significant at 5% level.
Source: SID database.

Table 62. Spearman Rank Correlation for share of firms in the industry introducing new processes in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.83*	1.00	
CIS 4	0.88*	0.93*	1.00

* significant at 5% level.
Source: SID database.

Table 63. Spearman Rank Correlation for share of firms in the industry applying for a patent in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.94*	1.00	
CIS 4	0.87*	0.83*	1.00

* significant at 5% level.
Source: SID database.

Table 354. Spearman Rank Correlation for total innovation expenditure per employee in the industry in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.93*	1.00	
CIS 4	0.91*	0.86*	1.00

* significant at 5% level.
Source: SID database.

Table 365. Spearman Rank Correlation for share of firms in the industry aiming to reduce labour cost through innovation in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.85*	1.00	
CIS 4	0.66*	0.82*	1.00

* significant at 5% level.
Source: SID database.

Table 376. Spearman Rank Correlation for share of firms in the industry aiming to open up new markets through innovation in the three CIS waves.

	CIS 2	CIS 3	CIS 4
CIS 2	1.00		
CIS 3	0.91*	1.00	
CIS 4	0.74*	0.85*	1.00

* significant at 5% level.
Source: SID database.