RD and productivity in high-tech manufacturing: a comparison between Italy and Spain

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R&D AND PRODUCTIVITY IN HIGH-TECH MANUFACTURING: A COMPARISON BETWEEN ITALY AND SPAIN

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Abstract

Using data for twelve manufacturing industries over the period 1980-2006, we perform for Italy and Spain a dynamic panel estimation of the long-run elasticity of TFP with respect to R&D capital. The results show that in Spain high-tech industries have experienced a similar or slightly higher R&D elasticity than their Italian counterparts. This is mainly attributable to what occurred from the mid 1990s onwards when, thanks to increasing R&D efforts, the Spanish industries have been able to catch up with the respect to the Italian ones. The policy implications of the above findings are discussed.

Keywords: Manufacturing industries. Italy and Spain. Productivity growth. R&D capital.

JEL Codes: O4, O3, L6.

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1. Introduction

Both in the light of endogenous growth models and a number of empirical studies, the weak productivity performance of European countries as opposed to that recorded, especially during the second half of the 1990s, by the US has been mainly ascribed to the lower accumulation of knowledge and human capital. The same motivation plays an important role in explaining the productivity differences among European countries. Knowledge capital, usually approximated by the stock of cumulated R&D investment, has been found particularly effective in boosting the productivity of the manufacturing sector which, in all the developed economies, performs the lion's share of private business R&D.

This paper analyses the relationship between the changes of R&D capital and those of Total Factor Productivity (TFP) across the manufacturing industries of Italy and Spain over the period 1980-2006. The main reason for comparing these two Southern European countries only is that they still maintain a strong presence of low- and medium-tech manufacturing industries, a structural feature that differentiates them from the Central and Northern Countries of the EU. In consequence of that, Italy and Spain are usually classified as technology-followers, and the fact that their industries invest in R&D much less than their European partners is associated with the above structural characteristic.

Accordingly, the focus on Italy and Spain allows us to deal with some interesting questions. Is R&D investment an effective productivity driver also for countries not specialised in high-tech manufacturing? Having a relatively lower level of R&D capital, do Spanish industries enjoy lower productivity benefits from R&D as opposed to their Italian counterparts? If not, is the change in R&D capital - rather than its level - playing a dominant role?

To address the above issues, we compute for twelve manufacturing industries of Italy and Spain consistent annual indicators, over the period 1980-2006, of their TFP and R&D capital stock. Then, with these data, we perform a dynamic panel analysis based upon an Error Correction Model (ECM), able to disentangle the long-run effect of R&D from short-run deviations. Moreover, in our econometric specifications, we estimate the long-run elasticity of TFP with respect to the stock of R&D capital arising for two industry groups: one composed of high-tech or R&D-intensive industries, and the other including less technology-based industries. Fist of all, in line with previous studies, we found that, in both countries, the long-run impact of R&D is positive and significant only for high-tech industries. Secondly, the estimated R&D elasticity turns out to be almost the same in Italy and Spain. Finally, by neglecting the last years characterised by a declining productivity growth (2001-2006) in the R&D-intensive industries of both countries, it emerges that the effect of R&D on TFP is slightly higher for the Spanish industries.

The above findings suggest that also in countries that are far from the technological frontier, the knowledge-intensive manufacturing industries attain significant productivity benefits from their R&D efforts. Moreover, the (at first sight unexpected) results for the Spanish industries indicate that for technological followers, i.e. countries having a relatively low level of R&D capital compared to technology leaders, it is crucial to invest in R&D at increasing rates. In fact, while from the mid 1990s the R&D capital of Italian industries has been stagnant, that of the Spanish ones has remarkably increased. It should be added that, in Spain, the intensification of research efforts has been fostered by a policy of very generous R&D tax incentives, mainly exploited by large companies belonging to technology-based industries. The Italian governments, on the contrary, have not ascribed the same priority to R&D policies: these have been mainly based on generalised subsides, i.e. not targeted to R&D-intensive industries, provided discontinuously and with limited amounts of public funds.

The paper is organised as follows. Section 2 provides a brief overview of the aggregate productivity slowdown experienced in Italy and Spain from 1995 on, by stressing that the former country has encountered particular difficulties in manufacturing while the latter in the rest of the economy. Section 3 is devoted to a descriptive analysis of the performance of Italian and Spanish manufacturing industries in terms of TFP growth and R&D investment over different time periods between 1980 and 2006: in this exam, R&D-intensive industries are distinguished from those less based on technology, also showing their relative weight in the two economies. In Section 4 we describe how industry level data concerned with TFP and R&D capital stock have been computed. In Section 5 we present the country-specific estimates by employing an ECM to link TFP and R&D capital across manufacturing industries. Finally, Section 6 contains concluding remarks and policy considerations.

2. Italy and Spain's productivity slowdown

Table 1 compares between Italy and Spain the annual rates of growth of per capita GDP and its two main components (occupation ratio and labour productivity) over the periods 1980-1995 and 1995-2006. During the former, also thanks to its entrance in the European Union in 1986, Spain performed slightly better than in Italy in term of GDP per capita growth. In any case, the growth of both countries was mainly based upon the increase in labour productivity. In the subsequent period, instead, the growth of productivity plummeted in both countries, although more in Spain. However, contrary to Italy, Spain was able to improve remarkably its performance in terms of GDP per capita by means of a staggering increase in the occupation ratio. The country created 7.2 million new jobs between 1995 and 2004, and reduced the unemployment rate from 25% of the early 1990s to 8% (Mas - Quesada, 2007). Along with a rise of female occupation, the employment expansion was due to a dramatic increase in immigrant workers (2.4 million between 1995 and 2006).

Table 1 – GDP per capita decomposition for Italy and Spain:
1980-2006 (annual average rates of change)

	GDP per capita*	Occupation ratio	Labour productivity
Italy			
1980-1995	1.82	0.05	1.77
1995-2006	1.43	0.94	0.49
Spain			
1980-1995	2.27	0.23	2.04
1995-2006	3.49	3.31	0.17

*GDP per capita in 1990 US$ (converted at Geary Khamis PPPs)
Source: The Conference Board Total Economy Database, January 2010.
(http://www.conference-board.org/economics/database.cfm)

The success story of Spain during the last decade is almost entirely ascribable to the above phenomenon, the counterpart of which, however, has been a substantial decline in productivity growth. Obviously, the two aspects intertwine, because most of the new jobs consisted of low-skilled occupations particularly concentrated in traditional business activities. Thus, as stressed by Mas - Quesada (2007) and Mas et al. (2008), it is not surprising that the productivity problem of the Spanish economy rests upon the poor performance - in terms of both labour and Total Factor Productivity - recorded especially by the construction sector and, then, by private services (aside from financial intermediation) and some traditional manufacturing industries.

Table 2 confirms these findings by showing that, in Spain, both during 1980-1995 and 1995-2006 the labour productivity changes recorded by the manufacturing sector are higher than those experienced by the whole economy. The same occurs by looking at TFP (computed according to a standard Cobb-Douglas production function; see Section 4 for details): in this case, the growth rates were generally negative during the last period but, in manufacturing, TFP declined less than in the entire economy.
The Italian productivity slowdown experienced over the last decade is of different nature. Most of the studies addressing this issue have documented that, from the mid 1990s to the early 2000s, the decline of the Italian productivity growth was more intense in manufacturing than in the overall economy (see, among others, Bassanetti et al., 2004; Venturini, 2004; Jorgenson, 2005, Daveri - Jona-Lasinio, 2005; Mas et al., 2008).
The same conclusion arises from Table 2. Contrary to what occurred over 1980-1995, during the last period labour productivity growth in manufacturing was in line with that recorded by the whole Italian economy. In terms of TFP, the performance of the manufacturing sector was much worse, being characterised by a negative change.

Table 2 – Labour productivity and TFP: 1980-2006 (annual average rates of change)

	Labour productivity		Total Factor productivity	
	Total Economy	Manufacturing	Total Economy	Manufacturing
Italy				
1980-1995	1.76	2.86	1.24	2.17
1995-2006	0.28	0.36	0.08	-0.20
Spain				
1980-1995	1.69	2.60	0.29	0.52
1995-2006	0.20	0.70	-0.40	-0.30

Source: OECD STAN (STructural ANalysis) Database, 2009 release (www.oecd.org/sti/stan/)

To summarise, starting form the mid 1990s, the Italian decline of TFP has been particularly intense in manufacturing, while that of Spain has been relatively more pronounced in the rest of the economy.

3. Productivity and R&D in manufacturing industries

This section illustrates in more details the role and performance of the manufacturing industries of Italy and Spain. In particular, we address in a descriptive way the central issue of the paper, i.e. the relationship between productivity growth and R&D investment. In Section 5 the same topic will be examined by means of an econometric analysis.
The focus on manufacturing industries only is justified by the fact that, in all the most advanced economies (Italy and Spain included), they account for about 80% of the R&D performed by the business sector (Zachariadis, 2004). As a consequence, although R&D could also affect the efficiency of some private service activities, such a variable is expected to play a greater role in boosting manufacturing productivity. However, as a further qualification, it is reasonable to assume that the strength of the relationship between productivity and in-house (or direct) R&D will vary remarkably among different manufacturing industries. In this regard, Verspagen (1995) and, more recently, Brandt (2007) and Ortega-Argilés et al. (2010) have found that the impact of R&D investment on productivity growth is positive and significant only for high-tech or R&D-intensive industries. This occurs not only because the latter invest more in R&D, but also because they are

characterised by greater technological opportunities and, thus, are more apt to translate their technological or knowledge investment into higher productivity gains (see, in particular, Ortega-Argilés et al., 2010).
In this paper we do not follow the classification of high-, medium-, and low-tech industries provided by the OECD (Htzichronoglou, 1997). Instead, we group together the two-digit manufacturing industries of Italy and Spain recording a relatively higher intensity of R&D expenditures on value added: Chemicals & Pharmaceuticals; Machinery & Equipment; Electrical & Optical Equipment; Transport Equipment. These industries, which we label as "R&D-intensive", perform the bulk of manufacturing R&D in all advanced countries. Looking at the period 2000-2006, in Germany 92% of total manufacturing R&D is concentrated in such industries, while in Italy and Spain the same percentages are, respectively, 88 and 78.
In what follows, we compare between Italy and Spain (and, in one case, also Germany, as a useful term of reference) the productivity growth of total manufacturing and R&D-intensive manufacturing industries, their weight in the total economy, and the intensity of their R&D expenditures.

Table 3 – TFP annual average rates of change

	Manufacturing	R&D-intensive mfg. industries*
Italy		
1980-1990	2.14	3.31
1990-2000	1.35	1.08
2000-2006	-0.75	-0.71
Spain		
1980-1990	0.62	2.57
1990-2000	0.28	1.24
2000-2006	-0.73	-0.86

*= Chemicals & Pharmaceuticals; Machinery & Equipment; Electrical & Optical Equipment; Transport Equipment.
Source: see Table 2.

In order to better highlight the country differences in terms of TFP growth, we break down the period 1980-2006 into three sub-periods: 1980-1990, 1990-2000, and 2000-2006. Table 3 shows that both in Italy and Spain there has been a continuous and widespread slowdown in manufacturing TFP. However, while in Italy the reduction of TFP growth was particularly severe between the first two decades, in Spain the same phenomenon occurred later, i.e. between the 1990s and the period 2000-2006. Another important finding is that the Italian manufacturing industries performed always better than their Spanish counterparts with the only (tough relevant) exception of the R&D-intensive industries during the 1990s. In this decade, the technology advanced industries of Spain experienced a TFP growth higher than that of the entire manufacturing sector and began a moderate process of caching up with respect to the Italian ones. Such a process, however, was reversed in the 2000s when the Spanish advanced industries experienced a remarkable productivity decline, in line with that recorded by the Italian ones.
To illustrate the importance of manufacturing industries in the two economies, table 4 shows their shares on total value added at current prices. From the 1980s to the 2000s, the weight of the whole manufacturing sector has substantially declined in both countries, though the reduction has been more evident in Spain. Also the weight of the R&D-intensive industries has diminished. However, in Spain but not in Italy, the decrease in the latter has been less intense than that recorded by manufacturing. In any case, the manufacturing sector of the two countries under examination is still

dominated by low-tech industries performing little R&D (see Table 5 for a comparison with Germany).

Table 4 – Relative shares of value added

	Manufacturing/ Total economy	R&D-intensive mfg. industries/ Total economy
Italy		
1980-1990	25.6	9.16
1990-2000	21.8	7.54
2000-2006	19.5	6.97
Spain		
1980-1990	26.3	8.16
1990-2000	20.3	6.74
2000-2006	16.8	5.68

Source: see Table2

At first sight, the above structural feature seems the major reason of the relatively low intensity of R&D expenditure recorded by the manufacturing sectors of Italy and Spain as opposed to those of their major European counterparts. However, a closer inspection to the data reveals that the above motivation does not play a dominant role.

Table 5 – R&D intensity in total and R&D-intensive manufacturing industries and weight of the latter in total manufacturing

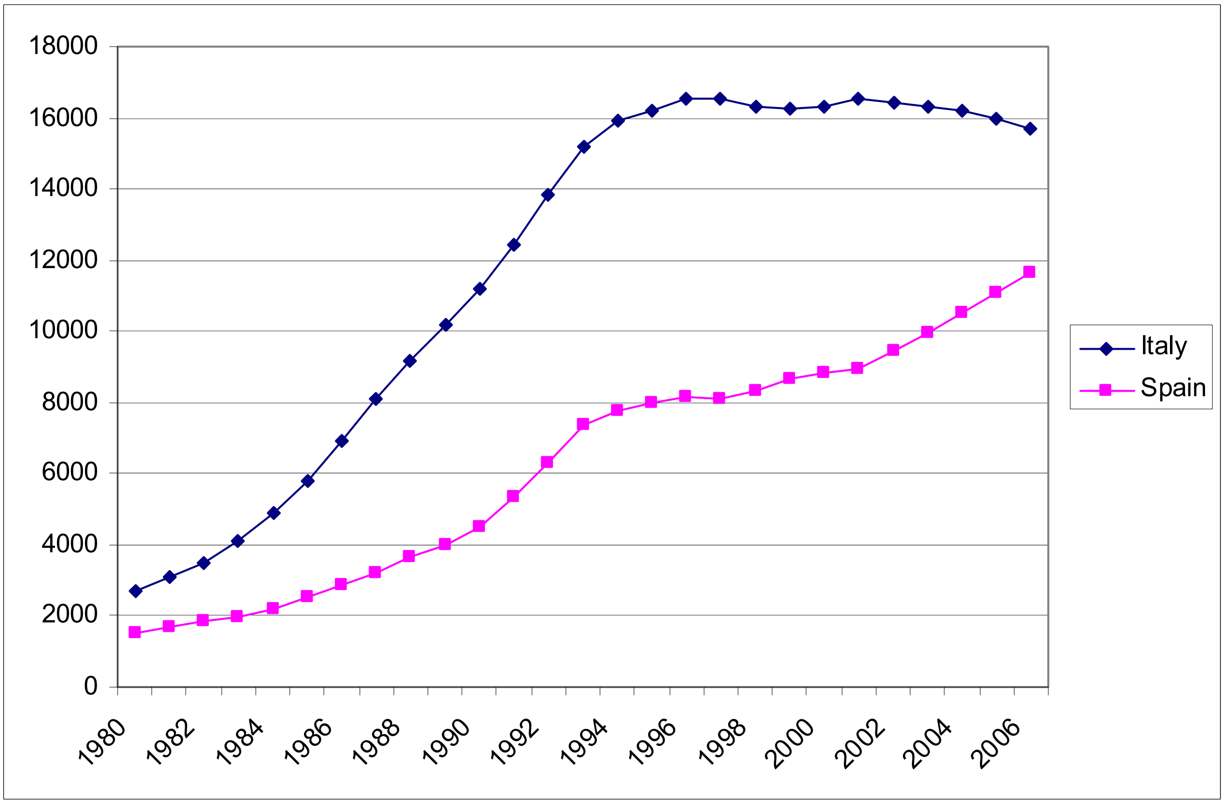
	R&D intensity in total manufacturing	R&D intensity in R&D-intensive mfg. industries	Share of value added of R&D-intensive industries on total manufacturing
Italy			
1980-1990	2.4	5.8	36.42
1990-2000	2.4	6.3	35.61
2000-2006	2.3	5.5	37.25
Spain			
1980-1990	1.2	3.1	31.96
1990-2000	1.9	4.5	34.63
2000-2006	2.3	5.1	34.13
Germany			
1980-1990	6.1	10.4	53.32
1990-2000	6.9	12.0	52.74
2000-2006	7.7	12.7	55.67

Sources: see Table 2 and ANBERD (Analytical Business Enterprise Research and Development) Database, 2009 release (http://stats.oecd.org).

Table 5 shows that in the Italian and Spanish manufacturing industries the shares of R&D expenditure on value added have always been much lower than that recorded by Germany. Still over the period 2000-2006 the R&D intensity in total manufacturing is 7.7% in Germany against 2.3% in Italy and Spain. It must be noticed, however, that the gap in R&D engagement is even

larger when the sub-set of R&D-intensive industries is considered (12.7% in Germany versus 5.5% in Italy and 5.1% in Spain). This suggests that the weak R&D performance of Italy and Spain is not driven by their specialisation patterns, as it can be only in part explained by the low presence of technology advanced industries: such sectors invest in R&D much less than the North-European counterparts (for a detailed comparison across countries and industries see Ulku, 2007).
To support the above conclusion, a simple exercise can be performed for the period 2000-2006. If Italy and Spain had the same share of R&D-intensive industries on total manufacturing as recorded by Germany (55.7%, instead of, respectively, 37 and 34%; see the last column of table 5), but maintained their actual propensities to carry out research activities, their R&D intensity in total manufacturing would increase from 2.3 to 3.2% only. On the contrary, by keeping the actual value added shares of R&D-intensive industries, if Italy and Spain had the same R&D propensity of Germany, their R&D intensity would increase, respectively, up to 5.5 and 5.2%. In short, to reduce the technology gap, structural changes in favour of R&D-intensive industries appear by far less effective than a radical shift in the propensity to carry out R&D[1]. Moreover, the increase in R&D efforts should be mainly, if not entirely, concentrated in technology-based industries (for a similar policy indication see Ortega-Argilés et al., 2010). The latter, as already observed, not only invest more resources in R&D, but also have higher opportunities to translate technological innovations into productivity growth.
Have Italy and Spain followed the above indications in order to reduce their R&D gap? The changes in the R&D intensities illustrated in Table 5 already suggest that the answer is fairly positive for Spain, and clearly negative for Italy.

Figure 1 – R&D capital stock per employee in R&D-intensive manufacturing industries



[1] Using data for 36 industries concerned with 14 European Countries and the United States, Erken - van Es (2007) reach a similar conclusion: the fact that high-tech industries are more present in the US economy accounts for only 25% of the European gap in terms of R&D intensity; the remaining 75% is due to and intrinsic effect (i.e. European industries perform less R&D).

However, to get a dynamic picture of the innovative efforts of the two countries consistent with the econometric analysis performed in Section 5 we can use an alternative indicator: the R&D capital stock of technology-intensive manufacturing industries, i.e. the flows of R&D investment cumulated over time and adjusted for a given depreciation rate (see Section 4 for details). Due to the different size of the Italian and Spanish sectors, the level of R&D capital can be normalised by the number of employees (Figure 1). From 1980 to 1997 the Italian industries increased the stock of R&D per employee more than their Spanish counterparts. After 1997, instead, their R&D capital became almost constant and slightly diminished during the 2000s. On the contrary, the knowledge capital of Spanish industries continued to grow so that they were able to halve the gap recorded in 1997 with respect to the Italian ones.
In conclusion, although both in Italy and Spain the R&D propensity is still below that of the most technology advanced countries, during the last decade Spain has behaved as a typical technological follower should do, while the R&D efforts of the Italian industries have slowed down. To what extent these different patterns of R&D investment have affected manufacturing productivity is the topic of the next sections.

4. R&D capital and TFP growth: analytical framework and data description

The analytical framework is drawn on Sterlacchini and Venturini (2007), where the relationship between R&D and TFP variables is shaped as a Cobb-Douglas production function augmented with R&D (or knowledge):

$$Y_{it} = AL_{it}^{\alpha} K_{it}^{1-\alpha} RD_{it-1}^{\theta} \tag{1}$$

where the suffixes i and t denote industries and years, Y stands for value added at constant prices, L is a measure of labour input, while K and RD denote, respectively, the stock of physical (or tangible) capital and that of R&D (or knowledge) capital. For 'traditional' inputs L and K, constant returns to scale are assumed, while RD is inserted with a time lag of one year.[2]
Taking logs and assuming perfectly competitive markets, so that labour and tangible capital are paid according to their marginal productivity and α can be proxied by the labour share on value added s_L, a measure of TFP can be computed as a function of the R&D capital stock:

$$\ln TFP_{it} = \ln Y_{it} - s_{Li} \ln L_{it} - (1 - s_{Li}) \ln K_{it} = \eta_i + \theta \ln RD_{it-1} \tag{2}$$

where η_i is an industry specific effect, assumed constant over time, which should pick up any individual unobserved heterogeneity (due, for instance, to exogenous changes in technology, regulatory frameworks, etc.).
It must be stressed that, as far as the labour and capital inputs specifically devoted to R&D are already included in L and K (i.e. the inputs on the right-hand side of equation (1) are not corrected for double counting), θ must be interpreted as the excess elasticity of value added with respect to R&D capital. In other words, a positive value of this parameter should emerge only if the labour and capital inputs employed in the firms' R&D function are 'more productive' than those devoted to other functions (production, administration, and so on).
In order to estimate θ, we consider for Italy and Spain twelve two-digit manufacturing industries[3] for which the Structural Analysis (STAN) database of the OECD provides, over the period 1980-

[2] See Nucci (2008) for a discussion (and related estimates) on the effects of the presence of increasing returns to scale and monopoly power on TFP dynamics.
[3] Food, Beverage & Tobacco; Textile, Clothing & Leather; Wood & Wood Products; Paper, Printing & Publishing; Chemicals & Pharmaceuticals; Rubber & Plastics Products; Non-metallic Mineral Products; Basic Metals & Fabricated Metal Products; Machinery & Equipment N.E.C.; Electrical & Optical Equipment; Transport Equipment; Other

2006, consistent data (both at current and constant prices), on valued added, gross fixed capital formation, total employment and labour compensation.

For each industry, the stock of tangible capital (*K*) is computed according to the perpetual inventory method and assuming a geometric depreciation; annual data are mid-year adjusted (as in Van Ark et al., 2002). The initial (t_1=1980) capital stock is evaluated according to the procedure introduced by Hall - Mairesse (1995), $K_{i,1} = I_{i,1}/(g_i+\delta_i)$, where $I_{i,1}$ is the gross fixed capital formation (evaluated at 1995 constant prices) in industry *i* at time 1 t_1, and g_i is the average annual growth rate of real investment over the subsequent decade (from t_1=1980 to t_{10}=1990). As in Maffezzoli (2006), we estimate the depreciation rate δ_i, constant over time, as the ratio between consumption of fixed capital and gross fixed capital stock provided by the OECD with the STAN (STructural ANalysis) Database (2009 release: www.oecd.org/sti/stan/)[4].

Having computed the stock of tangible capital, we use the data on value added at 1995 prices, total employment (employees plus self-employed persons) and labour compensation on value added[5] with a view to obtain the annual log-level of TFP (as in equation (2)).

The next step refers to the computation of the R&D capital stock. For the manufacturing industries of Italy and Spain, we took the annual series of nominal expenditure on R&D provided by the OECD ANBERD (Analytical Business Enterprise Research and Development) Database (2009 release: http://stats.oecd.org) and converted them into 1995 prices by means of the industry deflator for value added. Then, we apply again the perpetual inventory method based on annual outlays expressed at 1995 prices. However, contrary to the data on tangible assets, R&D expenditures at industry level are available since 1973, so that we were able to evaluate the R&D stock in 1980 by taking into account also the R&D efforts of the previous seven years. To be added is that the R&D stock in 1973 is computed by applying the same procedure described above although; in this case, we assume a depreciation rate of 15 per cent, constant across industries and time, as usually done to build the R&D capital stock at firm and industry level (cf. Hall - Mairesse, 1995). In any case, as far as the growth and the depreciation rate of R&D outlays do not systematically change over time, the differences among industries will be incorporated into the fixed effect (η_i in equation (2)), so that the estimated elasticity of TFP with respect to R&D capital (θ) will not be affected by the choice of a different depreciation rate (Hall, 2006).

Before moving to the estimation results, an important consideration is in order. The framework depicted in equation (2) takes only into account the direct (within-industry) effect of R&D capital on TFP growth. In other words, the role of international and inter-industry R&D spillovers is neglected[6]. However, since we are dealing with two countries that are both technological followers, and have a similar composition of manufacturing industries, we can assume that the indirect effects of foreign and domestic R&D will not be so different and, then, will not alter the main conclusions arising from the estimation of the direct effect of knowledge capital[7]. It should also be added that

manufacturing industries. We excluded from the analysis the industry of Coke, Refined Petroleum Products & Nuclear Fuel; being mainly based on the supply of natural resources, such an industry is characterised by an erratic and anomalous behaviour in terms of TFP growth.

4 The consumption of fixed capital is computed as the gross fixed capital formation at time t minus the absolute variation of net capital stock between time t and t-1. Net and gross fixed capital stocks are built by OECD through a permanent inventory method accounting for the age and efficiency profile of different capital assets.

5 Labour compensation is augmented by the remuneration of self-employed workers by assuming that their compensation rate is equal to that of employees (OECD, 2001).

6 The effects on productivity exerted by international and/or inter-industry R&D spillovers are examined, among others, by Frantzen (2002), Añón Higón (2007) and Brandt (2007).

7 Aside from their direct effect on TFP, R&D activities are also aimed at sustaining an adequate absorption capacity (Cohen - Levinthal, 1989) which allows the industries of a country to remain as close as possible to the technological frontier. Accordingly, the impact of R&D on TFP growth also depends on the distance from the world technological leader (Griffith et al., 2004). In the case of Italy and Spain we can assume that such a distance has not been remarkably different over the period considered.

the cointegration estimation technique adopted in the next section is not affected by the bias related to the omission of such relevant variables (as well as to reverse causality, measurement errors, etc).

5. Estimation procedure and results

In this section we perform an estimation of the long-run relationship between TFP and R&D capital stock. Such a relationship, described in equation (2) of the previous section, is investigated, across Italian and Spanish industries and over time, by means of an Autoregressive Distributed Lags model, ARDL(1,1), of the following type:

$$\ln TFP_{it} = \alpha_{0i} + \alpha_1 \ln TFP_{it-1} + \alpha_2 \ln RD_{it-1} + \alpha_3 \ln RD_{it-2} + \varepsilon_{it} \quad (3)$$

in which all the parameters are assumed to be homogenous among industries aside from an individual fixed effect (α_{0i}).
Equation (3) can be then re-formulated as a dynamic panel Error Correction Model (ECM):

$$\Delta \ln TFP_{it} = \beta_{0i} + \beta_1 \Delta \ln RD_{it-1} + \beta_2 \ln TFP_{it-1} + \beta_3 \ln RD_{it-2} + \varepsilon_{it} \quad (4)$$

where $\beta_{0i}=\alpha_{0i}$, $\beta_1=\alpha_2$, $\beta_2=\alpha_1-1$, and $\beta_3= \alpha_2+\alpha_3$.
The ratio $\theta=-[\beta_3/\beta_2]$ is the long-run elasticity of TFP with respect to R&D capital, while β_1 reflects the short-run variations between the dependent and the explanatory variable. β_{0i} captures industry-fixed effects, while ε_{it} is a well-behaving error term.
Equation (4) can be extended in order to assess the role played by the most R&D-intensive industries: Chemicals & Pharmaceuticals; Machinery & Equipment; Electrical & Optical Equipment; Transport Equipment. For these industries, according to the discussion developed in Section 3, the long-run relationship between knowledge capital and TFP should be stronger and more statistically significant than for the industries less based on innovation and knowledge.
To test the above hypothesis, in the final specification we included two dummy variables interacted with the lagged log-levels of TFP and RD:

$$\Delta \ln TFP_{it} = \beta_{0i} + \beta_1 \Delta \ln RD_{it-1} + \beta_2 \ln TFP_{it-1} + \beta_3 \ln RD_{it-2} + \beta_4 \, RI \ln TFP_{it-1} + \beta_5 \, RI \ \ln RD_{it-2} + \varepsilon_{it} \quad (5)$$

where RI assumes the value of one for R&D-intensive industries, and zero otherwise. β_4 and β_5 identify the marginal impacts of being one of these industries in explaining the dynamics of TFP and RD. Whereas the long-run elasticity of the reference (non RD-intensive) grouping is given by $\theta=-[\beta_3/\beta_2]$, that of the knowledge intensive sectors is defined by $\theta^{RI}=-[(\beta_3+\beta_5)/(\beta_2+\beta_4)]$.
The baseline ECM framework of equation (4) has been already used to analyse the long-run relationship between R&D and TFP at industry level. Añón Higón (2007) employs an ECM to distinguish the short- and long-run impact of R&D capital on the TFP of eight UK manufacturing industries examined over 1970-97. Cameron (2005) uses a similar framework to estimate the impact of R&D and human capital on the productivity gap between eleven Japanese and US industries observed during 1963-1989. Brandt (2007) applies an ECM to the cost functions of twenty-three manufacturing industries concerned with six major OECD countries (US, Canada, Japan, Germany France and Italy) and examined from 1980 to 1998. For each industry he obtains the long-run elasticity of costs with respect to R&D capital, whose absolute value is a proxy[8] of the parameter θ arising from the single industry estimates of equation (4). To be stressed is that the impact of R&D

[8] Actually, the estimates provided by Brandt derive from a cost function taken as the dual of a production function based on gross output (i.e. including material inputs along with labour, tangible capital and R&D capital); as a consequence, his findings cannot be rigorously compared to those derived from a value added production function.

capital on productivity growth estimated by Brandt turns out to be significant only for the most R&D-intensive industries: this finding, along with the evidence provided in Verspagen (1995) and Ortega-Argilés et al. (2010), supports the use of the specification depicted in equation (5).

The econometric analysis is performed by adopting the feasible generalized least squares estimator (FGLS). We allow for a heteroskedastic error structure with cross-sectional correlation as well as a first-order autoregressive error specific to each panel unit. All the estimated specifications include industry fixed effects to capture the time-invariant unobservable characteristics of the process under examination. Also included are common time dummies in order to account for stochastic shocks that may affect, to the same extent, TFP growth across industries; these co-movements could depend on technological proximity, a similar exposure to foreign competition, common fiscal policies, etc. In the following analysis, this econometric approach is applied - separately for Italy and Spain - to estimate equation (5) across the twelve manufacturing industries listed in the previous section (cf. footnote 3).

To exclude the possibility that our regression results are driven by spurious correlation, we first checked whether the series of TFP and R&D capital stock contain unit roots and, secondly, whether there exists a stationary relationship among them over a long-term horizon (cointegration). We found that both the above conditions hold (see the Appendix). As a consequence, we conclude that the parameters θ and θ^{RI} truly identifies the long-run impacts of R&D on TFP; in this regression framework, instead, the coefficient of the first-differentiated regressor (β_1) merely captures the short-run co-movement between dependent and explanatory variables and, as such, it cannot properly identify the direction of causality.

Table 6 – Panel ECM estimates of the R&D impact on TFP: equation (5)

	β_1	β_2	β_3	β_4	β_5	*Long-run R&D elasticity of non R&D-intensive industries* $\theta=-[\beta_3/\beta_2]$	*Long-run R&D elasticity of R&D-intensive industries* $\theta^{RI}=-[(\beta_3+\beta_5)/(\beta_2+\beta_4)]$
1980-2006							
ITALY	0.026**	-0.016**	0.000	-0.029**	0.009***	0.026	0.188***
	(0.049)	(0.043	(0.732)	(0.011)	(0.016)	(0.733)	(0.000)
SPAIN	0.031	-0.027***	0.000	-0.020**	0.010***	0.031	0.205***
	(0.124)	(0.000)	(0.960)	(0.022)	(0.005	(0.960)	(0.000)
1980-2000							
ITALY	0.033**	-0.022**	0.000	-0.035***	0.011***	0.033	0.188***
	(0.012)	(0.029)	(0.035)	(0.000)	(0.0009	(0.935)	(0.000)
SPAIN	0.044**	-0.033***	0.001	-0.025**	0.012***	0.044	0.229***
	(0.021)	(0.000)	(0.650)	(0.015)	(0.003)	(0.960)	(0.000)

** = Significant at a 5% level of confidence. * = Significant at a 10% level of confidence. P-values in brackets.

The results yielded by the FGLS estimation of the ECM described in equation (5) are shown in Table 6 which reports the estimates of slope coefficients (excluding industry fixed effects and time dummies), and the implied value of the long-run R&D elasticity of the reference group composed of non R&D-intensive industries (θ), and that of the R&D-intensive ones (θ^{RI}), i.e. the two crucial parameters of our analysis. The (non-linear) tests of significance of θ and θ^{RI} are carried out with the delta-method; since this statistics is distributed as a $\chi^2(1)$, the table also includes, below the estimated coefficients, the p-values associated with this test, along with those concerned with the slope parameters.

The top part of Table 6 shows the findings for the entire period 1980-2006. Focussing on the long-run impact of R&D on TFP, the first important results that must be stressed is that knowledge capital turns out to be a significant productivity driver only for the R&D-intensive industries; those less based on innovation and knowledge do not reap, in the long-run, any significant productivity gain from R&D. Such a result holds for both Italy and Spain with a high level of statistical significance, confirming the findings of previous studies carried out at industry level (see above).

The estimated value of θ^{RI} is 0.21 for Spain and 0.19 for Italy, suggesting that the R&D-intensive industries of both countries have been almost equally able to translate into TFP gains their R&D investment. Such a finding is noteworthy especially if one considers that, in the early 1990s, the Spanish industries lagged quite behind the Italian ones in terms of TFP growth and, especially, that of R&D capital stock (see Figure 1, Section 3). Then, starting from the mid 1990s, the R&D-intensive industries of Spain began a significant process of catching up, while the R&D stock of their Italian counterparts remained almost constant. As a consequence, in the long-run (i.e. considering the entire period 1980-2006), the former sectors were able to achieve the same productivity benefits from R&D as the latter.

The above interpretation is confirmed by a second round of estimates, reported in the bottom part of Table 6 and concerned with the period 1980-2000. In this way, we neglect the most recent years in which, contrary to the two previous decades, the R&D-intensive industries of both countries have recorded a decline of TFP (see Table 3, Section 3). With this time truncation, it emerges that the effect of R&D capital on the TFP of technology-based industries is a bit higher for Spain (0.23), while it remains at the same level as before for Italy (0.19). A plausible explanation for the stability of the relatively lower impact of R&D recorded by the Italian industries is that they have been entrapped into a declining path before their Spanish counterparts, which only in 2002 began to experience a remarkable decline of TFP. As far as the recent productivity difficulties in which they have incurred will not last in the future, it can be said that the long-run performance of the Spanish R&D-intensive industries is more satisfactory than that of the Italian ones.

To better qualify the above findings, it should be added that the long-run impacts of R&D on TFP estimated for Italy and Spain, albeit significant, are lower than those arising for more technology-advanced countries. In a previous paper, although based on a slightly different approach, we have shown that the manufacturing industries of the US and Germany attain higher benefits from an increase of R&D capital (Sterlacchini and Venturini, 2007). Preliminary results, based on the same model and time span considered in this paper, indicate that for the German R&D-intensive manufacturing industries the long-run elasticity of TFP with respect to R&D capital ranges from 0.4 to 0.5, i.e. twice the value found for Italy and Spain. Accordingly, even if the industries of the latter countries will raise their R&D efforts as the German ones, the benefits in terms of TFP growth will be much lower. However, in light of their poor productivity records, both Italy and Spain do not appear to be in a position to miss the above productivity gains (see the next section)

6. Concluding remarks and policy considerations

The econometric analysis concerned with twelve manufacturing industries of Italy and Spain examined over the period 1980-2006 has shown that, also in developed countries classified as technology followers, to invest in R&D (i.e. knowledge and innovation) is a crucial condition for boosting productivity growth. It must be stressed, however, that, in line with the evidence arising for technology advanced countries, the productivity enhancing effect of R&D is not generalised to the whole manufacturing sector, but confined to the industries that spend more in R&D. As a consequence, for countries like Italy and Spain, with a strong presence in low- and medium-tech manufacturing industries (see Section 3), a surge in R&D investment cannot guarantee a dramatic increase of the TFP concerned with the whole manufacturing sector (and, a fortiori, that of the entire economy). It is then obvious that if the productivity disease of the two countries has to be cured, a much wider set of therapies is needed. Among them, unless both Italy and Spain accept to nullify their presence in technology-based industries, raising massively R&D investment appears indispensable. In fact, to maintain and, possibly, increase such a presence, structural industrial policies aimed at strengthening high-tech industries could be useful (provided that they will not infringe the EU competition law), but R&D and innovation policies should be viewed as the most effective and viable measures.

In this paper, we found that, in the long run, the elasticity of TFP with respect to R&D capital recorded by R&D-intensive industries is slightly higher in Spain than in Italy. In particular, neglecting the last years of declining productivity growth (from 2001 to 2006), the estimated R&D elasticity is 0.23 for the Spanish industries and 0.19 for the Italian ones. The above findings suggest that if R&D capital increased by 5% annually for a sufficiently long period of time, the TFP of R&D-based manufacturing industries would grow by 1.15% per year in Spain and 0.9% in Italy. Looking at the annual growth rates of TFP experienced by these industries during the 1990s (1.24% in Spain and 1.09% in Italy; cf. Table 3), the above productivity increases – only induced by R&D – are extremely relevant. It should be added that the adopted hypothetical increase in R&D capital is realistic being that recorded by the Spanish industries over 1995-2006.

The above evidence provides useful insights to the debate on the Italian productivity decline. In this regard, the comparison with Spain is quite illuminating. Indeed, if the R&D elasticity arising for the industries of this country had been lower than that found in Italy, one could have concluded that the long-run impact of R&D on TFP tends to rise with the level of knowledge capital. In other words, thanks to increasing returns and spillovers, the countries overcoming a given threshold of knowledge capital in some industries would obtain, as compared to those with a lower level of R&D, more than proportional benefits. This would have been consistent with the prediction of the scale effect of R&D provided by the first-generation Schumpeterian endogenous growth theory (Jones, 1995).

The results for Spain, however, are at odds with the above interpretation and suggest that, in terms of long-run R&D elasticity, the outcomes of different countries cannot be exclusively associated with the size of R&D capital, but are also due to its changes over time. As a consequence, the relatively low impact of R&D capital on the TFP of Italian industries is likely to be explained by the decreasing rates at which they have been investing in R&D activities since the early 1990s, i.e. well before the stagnant situation of the last years. Such a 'dynamic' interpretation of the productivity decline of the Italian high-tech manufacturing is supported by the evidence arising for Spain after the mid 1990s: thanks to a surge of research efforts it has achieved, in terms of R&D-related productivity benefits, a similar or slightly better performance than the Italian technology-intensive industries.

The divergent behaviour in terms of R&D investment by manufacturing industries – increasing in Spain and stagnant in Italy – is due to variety of factors. Among them, the policy measures adopted in the two countries to sustain business research activities play a quite important role. From a comparison of the tax treatment of R&D investment adopted in OECD countries (OECD, 2002; Warda, 2006), it emerges that the Spanish system of R&D tax incentives, introduced in 1995 and extended in the subsequent years, has been the most generous one. For firms investing in R&D, the deductions from corporate taxes can reach as much as 30% of the level and 50% of the increment of R&D expenditures (OECD, 2007). Although these incentives could be applied for by small and medium-sized firms (SMEs) as well, they have been mainly exploited by the largest Spanish companies, most of which belonging to the R&D-intensive industries considered in this paper (especially, chemicals and pharmaceuticals, transport equipment, electrical and electronic equipment). In Italy, instead, the R&D tax incentives for large companies have been the lowest among OECD countries, while they have been particularly advantageous for SMEs. As the Spanish case suggests, the above discrimination in favour of smaller firms seems at odds with the aim of sustaining the R&D of the most technology-based industries. Moreover, it is not consistent with the fact that much of the Italian slowdown in R&D investment is due to the behaviour of its largest companies[9]: although an increasing number SMEs have been involved in R&D activities, their limited financial resources have not allowed them to compensate for the R&D drop of large companies. It should be added that the difficulties of Italian SMEs in performing R&D are mainly due to a lack of external finance (especially from banks) and a scarce development of venture capital. Accordingly, a favourable tax system does not seem a particular appropriate measure to foster their R&D investment.

In any case, the Italian R&D policy of the last decades, rather than on tax incentives, has been largely based on horizontal public subsides, i.e. not oriented to particular industries (see Potì, 2010). Along with the lengthy process required for their provision, the problems with these subsides is that they have been discontinuous over time and, often, the amount of funds has been far below that required for supporting an adequate number of innovative companies.

Thus, in terms of R&D policy, we believe that Italy has an urgent need to mobilise a greater amount of more stable resources (including tax incentives) to both reverse the trend experienced by large companies and sustain the growth of small technology-based firms. As suggested by our findings, in order to achieve substantial productivity gains, the above policy interventions should be particularly oriented towards the most R&D-intensive industries.

As far as Spain is concerned, it appears that both the extent and type of policies adopted in the last decade have been quite effective to foster the R&D investment in the more technology-based industries. However, this bright picture has been obscured by some recent events. First, if the productivity decline recorded by the Spanish high-tech industries from 2001 to 2006 has continued in the subsequent years, the effectiveness of the above policies should be seriously called into question. Secondly, even though the above phenomenon has not occurred, one wonders whether the Spanish government, in the face of the current need of reducing its public deficit, will maintain in the future its favourable framework of R&D incentives.

[9] Starting from the early 1990s, large state-owned companies - belonging, in particular, to the chemical and electronic industries - have been restructured and, then, partially or entirely privatised. These processes have induced a substantial downsizing or dismissal of many large R&D laboratories that have not been replaced by those of established or emerging high-tech companies. On the contrary, Olivetti, one of the major European producers of office machinery, entered in a deep crisis in 1994 and, gradually, went out of the IT market. Starting from the mid 1990s, most of the large Italian companies have reduced their R&D investment (Sterlacchini, 2004) and the industry data used in our empirical analysis are a clear reflection of that phenomenon.

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APPENDIX: Unit roots and cointegration tests

In the following, we employ the *t*-bar test developed by Pesaran (2007) to verify if, for each country, TFP and R&D capital (taken in log-levels) are non-stationary within the panel of industries. Such a test relaxes the assumption of independence and, thus, it is more robust to the presence of cross-industry correlation than the previous generation of panel tests. The *t*-bar test checks the null hypothesis that all the individual series have unit roots; it consists in the cross-sectional average of the ADF-type regressions carried out at industry level.
This procedure preserves much of the parameters' heterogeneity. By exploiting information along both the time-series and cross-sectional dimension, panel tests are by far more precise than the non-stationarity statistics based on individual times-series (Breitung - Pesaran, 2008).

Table A.1 – Panel unit roots and cointegration tests: 1980-2006

	Pesaran's test for unit roots[(a)]				Westerlund - Edgerton's test for cointegration[(b)]	
	TFP		R&D			
	t-bar	p-value	*t*-bar	p-value	τ_N	p-value
ITALY	-1.881	0.346	-1.660	0.653	-2.139	0.016
SPAIN	-1.375	0.921	-1.195	0.980	-1.888	0.029

(a) = Pesaran (2007) checks the null hypothesis that all individual series are non-stationary (H_0), against the alternative of heterogeneity (H1). Under H1 t-bar statistics diverges to a negative infinite (tabulated 5% critical value: -2.25).

(b) = Westerlund - Edgerton (2008) check the null hypothesis that there is no cointegration within the panel. The τ_N statistics test admits regime shift. It is distributed as a one-sided standard normal (5% critical value: -1.64).

The left part of Table A.1 shows that all our series are non-stationary at the standard level of confidence (5%). Hence, we can proceed to verify the presence of cointegration between productivity and knowledge capital following Westerlund - Edgerton (2008)[10]. They propose a general statistic test (τ_N) that controls for a broad set of econometric issues: heteroskedaticity, serially correlated errors, cross-sectional dependence and unknown breaks; the values of τ_N reported in the right-hand side of Table A.1 is obtained by allowing breaks both in the intercept and slope coefficients (so-called *regime shift*). According to the values assumed by the τ_N test, there is a long-run stationary (cointegration) between TFP and R&D in both (national) groupings of manufacturing industries.

[10] We thank Joakim Westerlund for providing us with the GAUSS codes used to implement his panel tests.