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ABSTRACT

The Job Creation Effect of R&D Expenditures*

In this study we use a unique database covering 25 manufacturing and service sectors for 16 European countries over the period 1996-2005, for a total of 2,295 observations, and apply GMM-SYS panel estimations of a demand-for-labour equation augmented with technology. We find that R&D expenditures have a job-creating effect, in accordance with the previous theoretical and empirical literature discussed in the paper. Interestingly enough, the labour-friendly nature of R&D emerges in both the flow and the stock specifications. These findings provide further justification for the European Lisbon-Barcelona targets.

JEL Classification: O33

Keywords: technological change, corporate R&D, employment, product innovation, GMM-SYS

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1. Introduction

Promoting R&D and innovation is one of the main targets of European policy, well represented by the Lisbon-Barcelona objective of achieving an R&D expenditure/GDP ratio of 3% (two thirds of which provided by corporate expenditures) by the year 2010 (see European Council, 2002; European Commission 2002). While the impact of innovation and R&D on productivity is unequivocally positive (for surveys of the empirical evidence on this subject, see Mairesse and Sassenou, 1991; Ortega-Argilés *et al.*, 2010), the assessment of the possible effects of technological change on employment is much more controversial. In particular, over the last two decades the diffusion of a “new economy” based on ICT technologies has led to a re-emergence of the classical debate on the possible adverse consequences of innovation on employment. On the one hand, the fear of technological unemployment as a *direct* consequence of labour-saving innovation has always emerged in ages characterised by radical technological change[1]. On the other, the economic theory pointed out the existence of *indirect* effects which can counterbalance the reduction in employment, due to process innovation incorporated in the new machineries. Indeed, in the first half of the 19th century, classical economists put forward a theory that Marx later called the "compensation theory" (see Marx, 1961, vol. 1, chap. 13, and 1969, chap. 18). This theory relies on different market compensation mechanisms which are triggered by technological change itself and which can counterbalance the initial labour-saving impact of process innovation (for an extensive analysis, see also Vivarelli, 1995, chaps. 2 and 3; Petit, 1995; Vivarelli and Pianta, 2000, chap. 2; Pianta, 2005).

Compensation mechanisms include both price and income effects. As far as the former are concerned, process innovation leads to a decrease in the unit costs of production and - in a competitive market - this effect is translated into decreasing prices; in turn, decreasing prices stimulate a new demand for products and so additional production and employment[2]. As for the latter, in a world where competitive convergence is not instantaneous, it is observed that during the lag between the decrease in costs due to

[1] For instance, the striking response of the English workers to the first industrial revolution was the destruction of machines under the charismatic leadership of Ned Ludd in the industrial areas and of Captain Swing in the countryside (see Hobsbawm, 1968; Hobsbawm and Rudé, 1969).

[2] This mechanism was singled out at the very beginning of the history of economic thought (see Say, 1964) and has been re-proposed more recently (see Neary, 1981; Hall and Heffernan, 1985; Dobbs, Hill and Waterson, 1987; Smolny, 1998).

process innovation and the consequent fall in prices, extra profits and/or extra wages may be accumulated by innovative entrepreneurs and their employees. On the one hand, additional profits may be invested and so new jobs are created[3]. On the other, additional wages may translate into higher consumption; in turn, this increase in demand leads to an increase in employment which may compensate the initial job losses due to process innovation[4].

Obviously, both the price and income compensation mechanisms can be more or less effective depending on: 1) the degree of market competition (monopolistic rigidities can hinder the decrease in prices due to process innovation); 2) the demand elasticity; 3) the "animal spirits" and agents' expectations, which can delay the translation of additional profits and wages into "effective demand" (for a critique of the compensation theory, see Pasinetti, 1981; Freeman and Soete, 1987; Vivarelli, 1995; Appelbaum and Schettkat, 1995; Pianta, 2005). Moreover, technological change cannot be reduced to only *process* innovation, since *product* innovation can imply the birth of entirely new economic branches where additional jobs can be created. Indeed, the labour-intensive impact of product innovation was underlined by classical economists (Say, 1964) and even the most severe critic of the compensation theory admitted the positive employment benefits which can derive from this kind of technological change (Marx, 1961, vol. I, p.445). In the current debate, various studies (Freeman, Clark and Soete, 1982; Katsoulacos, 1986; Freeman and Soete, 1987; Freeman and Soete, 1994; Vivarelli and Pianta, 2000; Edquist, Hommen and McKelvey, 2001) agree that product innovations have a positive impact on employment, since they open the way to the development of either entirely new goods or radical differentiation of mature goods.

Given this framework, this paper aims to test empirically the possible job creation effect of product innovation, proxied by business R&D expenditures at the sectoral level. In fact, while process innovation is mainly incorporated in the new vintages of fixed capital, R&D is mainly devoted to the promotion of new prototypes, the introduction of entirely new products, or the radical differentiation of existing products (see Rosenberg, 1976; Nelson and Winter, 1982; Dosi, 1988). Indeed, recent microeconometric studies – using data from the European Community Innovation Surveys (CIS) – have confirmed empirically how R&D expenditures are closely linked with product innovation, while innovative

[3] Originally put forward by Ricardo (1951), this argument has also been used by neo-classical thinkers such as Marshall (1961) and later developed into dynamic models by Sylos Labini (1969), Hicks (1973) and Stoneman (1983, pp. 177-81).

[4] See Pasinetti, 1981 and Boyer, 1988

investment (especially devoted to new machinery and equipment) turns out to be related to process innovation (see Conte and Vivarelli, 2005; Parisi, Schiantarelli and Sembenelli, 2006).

Hence, an important novelty of this paper is that its main focus of interest is shifted from the investigation of possible (disequilibrium) technological unemployment due to process innovation, to the detection of a possible job creation effect of product innovation. The rest of the paper is organised as follows. Section 2 puts forward an overview of the empirical literature on the relationship between technological change and employment; Section 3 presents the dataset and some descriptive evidence; Section 4 describes the econometric strategy and discusses the results; Section 5 briefly concludes.

2. Previous empirical evidence

In the light of the discussion in the previous section, it is obvious that economic theory cannot provide – *ex ante* - a clear-cut answer to questions about the employment effect of technological change. Hence, attention should be turned to empirical analyses which can take into account the different forms of innovation, their direct impact on labour, the various indirect effects (compensation mechanisms) and possible hindrances to these mechanisms.

Starting from the microeconomic papers, empirical analyses at the firm level are extremely useful in revealing the ways new products generate jobs and how labour-saving process innovations destroy them. In particular, the "labour-friendly" nature of product innovation turns out to be particularly obvious in some microeconometric studies (see Entorf and Pohlmeier, 1990; Brouwer, Kleinknecht and Reijnen, 1993). The main shortcoming of this kind of analysis consists in a "positive bias" which tends to underline the positive employment consequences of innovation. In fact, once the empirical analysis is developed at the level of the single firm, innovative firms tend to be characterised by better employment performances since they gain market share because of innovation. Even when the innovation is intrinsically labour-saving, these analyses generally show a positive link between technology and employment since they do not take into account the important effect on the rivals, which are crowded out by the innovative firms (the so-called "business stealing" effect; see Van Reenen, 1997).

However, even when taking the business stealing effect into account, Piva and Vivarelli (2004 and 2005) find evidence in favour of a significant and positive effect of innovation on employment at the firm level (although the relevant coefficient turns out to be very small in magnitude).

Interestingly enough, Greenan and Guellec (2000), using data from French manufacturing sectors over the period 1986-90, find a positive relationship between innovation (both product and process) and employment at the firm level. Nevertheless, at the sectoral level, their results confirm the idea that only product innovation creates additional jobs, while process innovation generates jobs within the innovative firm but at the expense of the competitors, leading to an overall negative effect at the sectoral level. This latter result shows that the business stealing bias can be corrected when empirical analysis is carried out at the sectoral level. However, sectoral analyses too can be affected by either a negative or a positive bias, according to the observer's point of view (manufacturing *vs* services). For instance, Pianta (2000) and Antonucci and Pianta (2002) found an overall negative impact of technological change on employment in manufacturing industries across five European countries, while Evangelista (2000) and Evangelista and Savona (2002) found a positive employment effect in the most innovative and knowledge-intensive service sectors and a negative one in the case of financial-related sectors and most traditional services like trade and transport.

For these reasons, in this paper we will consider both manufacturing and service sectors. As an example of previous evidence using manufacturing and services together (using CIS cross-sectional sectoral data on relevant innovations for different European countries), Bogliacino and Pianta (2010) find a positive employment impact of product innovation (against a negative one of process innovation)[5].

Another limitation of sectoral analyses is that they cannot take into account the intersectoral indirect (compensative) effects of technological change, as can be done when the analysis is conducted at the aggregate/macroeconomic level. However, macroeconomic studies suffer from other important shortcomings. Firstly, technological change in general and ICT diffusion in particular are difficult to measure: traditional indicators such as R&D (input indicator), patents and relevant innovations (output indicators) are seldom completely reliable at the national level and are often unable to represent fully technological change at the level of the entire economy. Secondly, the final macroeconomic employment

[5] See also Vivarelli, Evangelista and Pianta (1996).

impact of innovation depends on economic and institutional mechanisms such as macroeconomic and cyclical conditions, labour market dynamics and regulations, the trends in working time and so on. These problems make empirical assessment of the macroeconomic relationship between technology and employment extremely challenging (see Sinclair, 1981; Layard and Nickell, 1985).

However, at the macroeconometric level too the argument that product innovation is the main driver of a possible positive relationship between technological change and employment is confirmed. For instance, Vivarelli (1995, chaps. 7, 8 and 9) and Simonetti, Taylor and Vivarelli (2000) have proposed a simultaneous equation macroeconomic model able to take into account jointly the direct labour-saving effect of process innovation, the different compensation mechanisms with their own hindrances, and the job-creating impact of product innovation. Running 3SLS regressions usingUS, , Italian, French and Japanese data over the period 1965-1993, the authors show that the more effective compensation mechanisms are a) via a decrease in prices and b) via an increase in wages. Product innovations turned out to be job-creating everywhere, although particularly labour-intensive in the technological leader country, namely the US.

Given the limitations of both the microeconomic and macroeconomic studies, in this paper we will adopt a sectoral approach. In the next section the available dataset is described and some preliminary descriptive evidence proposed.

3. Dataset and descriptive statistics

Our database includes manufacturing and market services, and covers the 1996-2005 period for 15 European countries, including the main ones, for a total of 2,295 observations (balanced panel). We have used OECD STAN for most of the information, coupling it with OECD ANBERD as far as business R&D is concerned. In particular, we have extracted the data on value added, employment, gross labour compensation and gross fixed capital formation from the former, while we have used the latter as a source for the R&D data.

Taking into account the availability and reliability of the original OECD data, we have considered the following countries: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Italy, Netherlands, Portugal, Spain, Sweden, United Kingdom.

Our unit of analysis is the industry at the two digit ISIC code; the industries included are listed in Table 1. The main limitations come from the availability of R&D data in ANBERD.

Value added has been deflated using the sectoral deflators provided by STAN, which take hedonic prices into account. All other nominal variables have been deflated using GDP deflators (taken from the IMF computations). We have consider 2000 as the base year. For non-euro countries, we have transformed data into euros using nominal exchange rates from OECD sources. Finally, we have corrected for purchasing power parities using PPP exchange rates from Stapel et al. (2004).

The distribution of employment is far from being uniform across sectors; the changes in shares over the investigated period follow the long-term trend of an increase in the importance of services at the expense of manufacturing[6].

Moving to R&D expenditure, we can state that the sectoral figures are fairly stable over time: a simple sectoral regression of R&D expenditures on a constant and the first R&D lag - with robust standard errors – gives a significant coefficient equal to 0.98 for the lagged term, showing an (expected) high degree of persistence in the R&D variable[7].

6 In the period 1996-2005 the industries that every year account for at least four percent of total employees are: food, drink and tobacco; wholesale trade; retail trade; hotels and catering; inland transport; other business activities. This evidence confirms the relevance of services. Those industries that account for more than two and less than four percent over the entire period are: fabricated metal products; mechanical engineering; motor vehicles; sales and maintenance of motor vehicles; communications; financial intermediation. All other industries maintain a size of less than two percent.

7 The overall R&D expenditure (in PPP 2000 constant billion euro) was 70.6 in 1996, constantly increasing over the whole period, arriving at 96.80 in 2005, with an average annual rate of increase of 3.57 percent.

Table 1: the database

INDUSTRIES	NACE	R&D intensity	
MANUFACTURING			
Food, drink & tobacco	15-16	1.12	LT
Textiles	17	1.33	LT
Clothing	18	0.44	LT
Leather and footwear	19	0.45	LT
Wood & products of wood and cork	20	0.31	LT
Pulp, paper & paper products	21	0.80	LT
Printing & publishing	22	0.12	LT
Mineral oil refining, coke & nuclear fuel	23	3.68	MT
Chemicals	24	15.49	MT
Rubber & plastics	25	2.93	MT
Non-metallic mineral products	26	1.34	MT
Basic metals	27	1.79	MT
Fabricated metal products	28	0.88	MT
Mechanical engineering	29	5.38	MT
Office machinery	30	14.57	HT
Manufacture of electrical machinery and apparatus n.e.c.	31	5.53	MT
Manufacture of radio, television and communication equipment and apparatus	32	25.01	HT
Manufacture of medical, precision and optical instruments, watches and clocks	33	11.93	MT
Motor vehicles	34	14.62	MT
Manufacture of other transport equipment	35	22.65	MT
Furniture, miscellaneous manufacturing; recycling	36-37	1.12	MT
SERVICES			
Sale, maintenance and repair of motor vehicles and motorcycles; retail sale of automotive fuel	50	n.a.	
Wholesale trade and commission trade, except of motor vehicles and motorcycles	51	n.a.	
Retail trade, except of motor vehicles and motorcycles; repair of personal and household goods	52	n.a.	
Hotels & catering	55	0.01	MT
Inland transport	60	n.a.	
Water transport	61	n.a.	
Air transport	62	n.a.	
Supporting and auxiliary transport activities; activities of travel agencies	63	n.a.	
Communications	64	n.a.	
Financial intermediation, except insurance and pension funding	65	n.a.	
Insurance and pension funding, except compulsory social security	66	n.a.	
Activities auxiliary to financial intermediation	67	n.a.	
Real estate activities	70	n.a.	
Renting of machinery and equipment	71	n.a.	
Computer and related activities	72	3.02	HT
Research and development	73	8.60	HT
Other business activities	74	0.29	MT

Notes: LT stands for Low-Tech; MT for Medium-Tech and HT for High-Tech industries, according to the OECD classification; the R&D intensity figures are the average ratio of R&D on value added over the investigated period 1996-2005; n.a. means that ANBERD does not provide R&D data.

Some descriptive statistics are reported in Table 2.

Table 2: descriptive statistics

		STANDARD DEVIATION		
	MEAN	**TOTAL**	**BETWEEN**	**WITHIN**
E	163.92	341.61	334.16	33.84
Y	8907.55	20298.94	20741.05	2585.27
R&D	269.00	839.00	801.00	137.00
I	1980.61	8360.16	8379.96	1472.32
w	29.15	20.54	20.36	3.43

Notes: E stands for number of employees, Y for Value Added, R&D for research and development expenditures, I for gross fixed capital formation and w for labour compensation.

As far as the sectoral composition of R&D expenditures is concerned[8], we can see that those industries that outspend are all in the manufacturing sector: chemicals; mechanical engineering; manufacture of radio, television and communication equipment and apparatus; motor vehicles and manufacture of other transport equipment, all of which represent individually more than 8% of total business R&D expenditure (continuously over the entire time span). The following represent individually a share of between one and eight percent over the whole period: food, drink and tobacco; rubber and plastics; fabricated metal products; office machinery; manufacture of electrical machinery; manufacture of medical, precision and optical instruments; watches and clocks; computer and related activities; research and development and other business activities. In Table 1 we report the average R&D intensity for manufacturing and service industries, measured as the share of corporate R&D on value added.

Finally, in Table 3 we give the correlation matrix between employment, gross fixed capital formation, value added, labour compensation per employee and business R&D expenditure (all in log scale).

8 As already mentioned, an important caveat is that ANBERD data do not cover all the service industries for which we have STAN data.

Table 3: correlation matrix

	E	Y	R&D	I	w
E	1				
Y	0.68*	1			
R&D	0.45*	0.78*	1		
I	0.68*	0.95*	0.83*	1	
w	0.05*	0.69*	0.76*	0.72*	1

Note: E stands for number of employees, Y for Value Added, R&D for research and development expenditures, I for gross fixed capital formation and w for labour compensation. Stars indicate significance at 0.05

As can be seen, the bivariate relationships between all the variables are all positive; this is not surprising and reflects the different sectoral economic climates across countries and over time. Obviously, for any interpretative purpose, a multivariate analysis controlling for country and time fixed effects is necessary (see next section).

4. Econometric Strategy and results

4.1 Methodology

Since the employment variable is highly persistent, we opted for a standard dynamic employment equation, where employment is autoregressive and depends on output (value added), wages, capital formation and R&D expenditures[9]. Thus, the estimated equation is:

$$\log(E_{ijt}) = \rho \log(E_{ijt-1}) + \alpha_0 + \alpha_1 \log(w_{ijt}) + \alpha_2 \log(Y_{ijt}) + \alpha_3 \log(I_{ijt}) + \alpha_4 \log(R\&D_{ijt}) + \beta' S + \gamma' T + \varepsilon_{ij} + u_{ijt} \qquad \textbf{(1)}$$

9 Indeed, the estimation of an employment equation is the standard example for which a panel dynamic specification turns out to be the proper econometric strategy (see Arellano and Bond, 1991).

where i, j, t indicate respectively industry, country and year; E is employment, w is labour compensation per employee, Y is value added, I is gross fixed capital formation, R&D is straightforward , S is a set of country dummies (to control for the possible impact of different national macroeconomic climates and specific economic policies), T is a set of time dummies (to capture both the economic business cycle and possible supply side effects in the European labour market), and the last two terms are the components of the error term. This equation is a standard labour demand, augmented with technology, as in Van Reenen (1997).

It is well known by scholars of panel theory that the above dynamic specification cannot be correctly estimated either by OLS or by the Within Group (fixed effects) estimator. Accordingly, we use GMM in both Arellano and Bond (1991) and Blundell and Bond (1998) versions, although the benchmark is the latter since the former has been demonstrated to be inferior in finite samples with high persistence, such as the one used in this study[10]. We compute a robust and Windmeijer (finite sample) corrected covariance matrix. While in an employment equation the wage term is obviously endogenous, high persistence[11] suggests potential endogeneity for the other variables, too; hence, to be on the safe side, we instrumented all of them.

We expect a positive and high coefficient for the lagged term, a negative α_1 capturing the standard labour demand inverse relationship between wages and employment, and a positive α_2 capturing the role of final demand. *A priori*, α_3 has no obvious sign, since capital formation is labour-expanding through its expansionary effect, and labour-saving through process innovation embodied in the new machineries (see Section 1). Finally, our main interest is in α_4, which we expect to be positive, given the close link between R&D and product innovation.

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[10] Data processing was carried out using Stata 11, and GMM estimations were conducted using the routine xtabond2; see Roodman (2005) for details.

[11] See the discussion on the R&D variable in the previous section.

4.2 Results

Table 4. Dependent variable: number of employees in log scale.

	(1) GLS	(2) WG	(3) GMM-DIF	(4) GMM-SYS
log(E_{ijt-1})	0.959	0.772	0.427	0.871
	[0.018]***	[0.034]***	[0.087]***	[0.035]***
log(w_{ijt})	-0.059	-0.170	-0.345	-0.095
	[0.025]**	[0.056]***	[0.101]*	[0.057]*
log(I_{ijt})	0.025	0.054	0.049	0.050
	[0.005]***	[0.011]***	[0.034]	[0.016]***
log($R\&D_{ijt}$)	0.005	0.008	0.047	0.025
	[0.001]***	[0.003]**	[0.012]***	[0.009]** *
log(Y_{ijt})	0.021	0.025	0.254	0.068
	[0.019]	[0.028]	[0.065]***	[0.035]*
const.		0.749		-0.179
		[0.211]***		[0.148]
S	Yes	No	No	Yes
T	Yes	Yes	Yes	Yes
N Obs	2295	2295	1907	2295
Hansen			159.55	196.20
p value			0.020	0.014
AR(1)			-3.02	-4.93
p value			0.002	0.000
AR(2)			-0.31	-0.88
p value			0.753	0.377

Notes: robust standard errors in brackets. E stands for number of employees, Y for Value Added, R&D for research and development expenditures, I for gross fixed capital formation and w for labour compensation. One, two and three stars indicate significance respectively at 10, 5 and 1 percent.

In Table 4 we report the results of the estimation of equation 1. In columns (1) and (2) we report GLS and fixed effect estimators (Within Group = WG) for completeness, while in columns (3) and (4) the GMM-DIF and GMM-SYS estimators are reported. Our most reliable benchmark is the last column, for the reasons explained above[12].

[12] Since we know that the bias of GLS and WG in estimating the lagged term's coefficient goes in opposite directions, the fact that the GMM-SYS estimation stands between the two can be considered as a confirmation of the adequacy of the chosen estimation methodology. By the same token, we consider column (3) with some suspicion. In terms of the standard GMM-SYS diagnostic test, the AR(1) and AR(2) LM tests are both reassuring, while the null of correct instrumentation (Hansen test) is rejected at the 5% level; however, we are not overly worried by the failure of the test for three reasons. First, neither the Sargan nor Hansen tests should can be relied upon too faithfully, as they are prone to weakness (Roodman, 2006, p. 12).

Some coefficients turn out to be as expected: in particular, the persistence nature of the employment variable is fully confirmed, demand (proxied by value added) operates as a driver of job creation, and the growth of wages negatively affects employment growth. Moreover, it seems that the expansionary impact of capital formation prevails.

Coming to our main point of interest, i.e. the effect of R&D expenditures, we can see that their impact on employment is positive and highly significant, although not so large in magnitude.

In order to test the robustness of our results, we run alternative specifications in which we replace capital and R&D flows with stocks (K and Z); in fact, it may well be the case that current employment is affected not just by the current flows of R&D expenditures and capital goods, but also by the cumulated stocks of knowledge and physical capital[13].

The K and Z stocks are built using the perpetual inventory method (PIM). Moreover, we classify industries into three technological groups (high-, medium- and low-tech, according to the standard OECD taxonomy, see Hatzichronoglou (1997), in order to differentiate the depreciation rates[14].

To initialise the PIM it is necessary to input historical capital and R&D growth rates; to avoid losing observations, we calculate the average compound growth rates over the period 1996-2001 and use them

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Second, in their Monte Carlo experiments, Blundell and Bond (2000) "observe some tendency for this test statistic to reject a valid null hypothesis too often in these experiments and this tendency is greater at higher values of the autoregressive parameter" (Blundell and Bond, 2000, p. 329). Third, the very large number of observations makes the occurrence of a significant Hansen test more likely. The reader will notice that in the following Table 5 the Hansen tests reveal a dramatic decrease in statistical significance.

[13] In particular, the cumulated stock of R&D expenditures can be considered a "structural" proxy of the revealed capacity to promote product innovation.

[14] In particular, considering respectively R&D and capital, we use 12% and 4% for the low-tech sectors, 15% and 6% for the medium-tech sectors, and 20% and 8% for the high-tech sectors. This procedure takes into account the fact that more technologically-advanced sectors are characterised (on average) by shorter product life cycles and by a faster technological progress, which accelerates the obsolescence of current knowledge and physical capital. The chosen values are centred on the 15% and 6% figures commonly used in the literature (Musgrave 1986; Bischoff and Kokkelenberg, 1987; and Nadiri and Prucha, 1996 for physical capital; Pakes and Schankerman, 1986; Hall and Mairesse, 1995; Hall, 2007 and Aiello and Cardamone, 2008 for knowledge capital). For obvious reasons, the literature assumes the depreciation of knowledge capital to be higher than that of physical capital.

as the growth rates for computing the initial 1996 stocks[15]. Thus the standard PIM formulae for the capital and R&D stocks are:

$$K_{ijt} = \begin{cases} (1-\delta_i)K_{ijt-1} + I_{ijt} & if\ t > 0 \\ \dfrac{I_{ijt}}{g_{ij} + \delta_i} & if\ t = 0 \end{cases} \quad \textbf{(2)}$$

$$Z_{ijt} = \begin{cases} (1-\lambda_i)Z_{ijt-1} + R\&D_{ijt} & if\ t > 0 \\ \dfrac{R\&D_{ijt}}{g_{ij} + \lambda_i} & if\ t = 0 \end{cases} \quad \textbf{(3)}$$

where g is the 1996-2001 compound growth rate at the industry level, δ is either 4, 6 or 8 percent and λ is either 12, 15, or 20 percent; I and R&D are the flows of capital and R&D, while K and Z are the corresponding stock measures.

Results are reported in Table 5, where column (1) includes the formulation with capital stock and R&D flow, column (2) the stock/stock specification, and column (3) the formulation with R&D stock and investment. We only report GMM-SYS estimations, with robust standard errors and Windmeijer correction. While in the first column we can see that there is no change in our coefficient of interest (in terms of either its significance or its magnitude), in the second and third specifications the coefficient of R&D stock (Z) loses some significance, although continuing to be statistically acceptable.

[15] Whenever the growth rates are negative we use zero.

Table 5. Dependent variable: number of employees in log scale (flows and stocks)

	(1) GMM-SYS	(2) GMM-SYS	(3) GMM-SYS
$\log(E_{ijt-1})$	0.880	0.917	0.880
	[0.037]***	[0.043]***	[0.039]***
$\log(w_{ijt})$	-0.037	-0.073	-0.133
	[0.049]	[0.055]	[0.052]**
$\log(K_{ijt})$	0.010	-0.001	
	[0.020]	[0.015]	
$\log(I_{ijt})$			0.041
			[0.015]***
$\log(Z_{ijt})$		0.012	0.025
		[0.006]*	[0.013]*
$\log(R\&D_{ijt})$	0.025		
	[0.008]***		
$\log(Y_{ijt})$	0.108	0.097	0.064
	[0.035]***	[0.039]**	[0.037]*
const.	0.024	-0.475	-0.324
	[0.580]	[0.194]**	[0.279]
S	Yes	Yes	Yes
T	Yes	Yes	Yes
N Obs	2014	1744	1989
Hansen	192.62	174.69	180.98
p value	0.022	0.159	0.083
AR(1)	-4.83	-4.63	-4.78
p value	0.000	0.000	0.000
AR(2)	-1.59	-1.66	-1.00
p value	0.112	0.098	0.319

Notes: robust standard errors in brackets. E stands for number of employees, Y for Value Added, R&D for research and development expenditures, Z for R&D stock, I for gross fixed capital formation, K for capital stock and w for labour compensation. One, two and three stars indicate significance respectively at 10, 5 and 1 percent.

5. Concluding Remarks

In this study, we use a unique 16-country, 25-sector, 10-year dataset to assess empirically the relationship between technological change (proxied by R&D expenditures) and employment, through panel GMM-SYS estimations. Consistently with previous theoretical and empirical literature (discussed in Sections 1 and 2), we find that R&D expenditures (which are good predictors of product innovation) may have a job-creating effect in the European manufacturing and service sectors. Interestingly enough, the labour-friendly nature of R&D emerges in both the flow and the stock specifications.

Hence, in addition to possible expansionary policies stimulating final demand and investment (both turning out to affect employment growth positively and significantly), R&D policy can exert a positive side effect on European job creation capacity.

While awaiting further confirmation of our results, our findings provide further justification for the European Lisbon-Barcelona targets.

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