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R&D Subsidies in Spain: are they Really Useful?

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Abstract
This article is aimed at estimating the impact of R&D subsidies on the demand for researchers, using information provided by a panel of Spanish firms belonging to the industrial and services sectors followed up during the 2004–2016 period. Estimates include corrections for the endogeneity bias generated by wages and by a set of variables measuring R&D public financing, as well as for the sample selection bias coming from the fact that the only wage data available are those from firms that are internal R&D performers and hire researchers. Estimate results show that public R&D financing has a positive and relevant impact on the demand for researchers. This result allows supporting the implementation of policies to promote public research funding in Spain, regardless of the origin of the funds received.

Keywords R&D expenditures · R&D subsidies · Researchers · Demand

JEL Classification H25 · J23 · O32 · O38

Introduction

The tasks carried out by scientists and technicians in research departments at firms are essential and necessary to generate new ideas that are later turned into specific innovation to increase productivity. This is why a great amount of internal R&D expenditure at firms is devoted to hiring researchers.[1] Such expenditure specifically

[1] A group defined by Rosenberg (1976) as "professional R&D personnel." This group counts on the support given by technicians and assistants, who are generally less qualified and with less responsibility in research teams (according to Rosenberg, the latter ones are the "non-professional R&D personnel"). Then, researchers will be the ones carrying out the most relevant tasks in research departments at firms.

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meant an average of 22.7% out of the total internal R&D expenditure of industrial firms in Spain (17.16% in case of services) for the 2004–2016 period, according to the *Technological Innovation Panel* [Panel de Innovación Tecnológica (PITEC)].[2] If we increase these percentages by the part of the expenditure devoted to the remuneration of technicians and assistants (17.08% and 10.27% in industry and services sectors, respectively), we will roughly conclude that 40% of internal R&D expenditure at Spanish industrial firms is devoted to research staff wages (27.43% in case of services). The remaining expenses are used for the purchase of machinery and equipment, leasing, training, etc.

Regarding the total amount of R&D expenditure, one of the main obstacles to the competitiveness of Spanish firms is their low innovative effort. Specifically, R&D expenditure as a percentage of Spanish GDP reached 1.24% in 2018, compared to an average of 2.03% in the European Union (EU-28), placing Spain far behind from the most advanced countries, such as Sweden (3.32%), Austria (3.14%), Germany (3.13%), or Denmark (3.03%).[3] As for the employment of researchers and assistants, the percentage of R&D personnel in relation to Spanish active population represented only 9.9% in 2018, compared to an average of 13.4% (EU-28), also far behind countries such as Denmark (21.1%), Finland (18.1%), Austria (17.8%), Sweden (16.9%), or Germany (16.3%).[4] This low innovative effort is surely one of the reasons why the Spanish labor market performs poorly. We must point out that the Spanish unemployment rate is permanently higher than the EU average (according to Eurostat, the unemployment rate was precisely 12.5% in March 2023, higher even than that of Greece and double than the European average (6% for the EU-27)).[5] In this sense, it is very convenient to carry out studies that analyze to what extent public authorities can encourage innovation and, thereby, indirectly increase competitiveness and employment.

Most countries implement public R&D financing programs by means of loans to firms, direct subsidies, tax reductions, etc. Some authors such as Suetens (2002) have found out that these subsidies do not always produce the expected effect, as they end up being used to cut companies' innovative effort, as they simply use public money to replace private funds without an actual increase of investment in company knowledge. Other authors such as Reinthaler and Wolff (2004) found evidence that companies awarded with public subsidies boost R&D employment. On the other hand, these authors observe that some of this financial contribution just causes an increase in researchers' wages.

In that sense, this paper tries to go deeply into this issue by assessing R&D subsidy impact on the demand for researchers within the framework of estimating a labor demand function. This requires taking into account both the impact of changes in researchers' wages and the endogenous nature of this variable. In fact, there are

2 The *Technological Innovation Panel* (PITEC) is an annual survey carried out by the *Spanish Statistical Office* [Instituto Nacional de Estadística (INE)].

3 See, FECYT (2020).

4 See, FECYT (2020).

5 See, Eurostat (2023).

hardly any precedents for this type of analysis in the Spanish case. The present study is meant to provide a new piece of evidence in this sense using information from a panel of Spanish industrial and services firms followed up during the period 2004–2016 (the *Technological Innovation Panel* (PITEC)).

The paper is structured as follows. Firstly, it summarizes the main articles addressing the study of public R&D financing effects on the demand for researchers. Then, the theoretical framework is exposed. It finally states the results obtained from estimating a researchers' demand function as well as the main conclusions of the article.

Literature Review

Many papers analyze the impact of subsidies granted to firms on their total R&D employment.[6] However, some R&D positions are not filled in by true researchers. In fact, technicians and assistants (clerical staff) carry out these positions assisting those who are actually doing the research. Besides, most of these studies assess the labor impact of such R&D subsidies without specifically estimating a labor demand function for researchers, as some relevant explanatory variables, such as their own wages, are omitted. Among these papers, Suetens (2002) analyzed the impact of subsidies granted to firms in Flanders on the total R&D employment, using a specific sample of relatively large R&D spenders. As the main result, Suetens observed the existence of a substitution effect between privately and publicly financed R&D personnel: "when ignoring fixed firm effects, about 60% of the publicly financed R&D would serve as a substitute for private R&D. When taking firm effects into account, almost complete substitution prevails" (p. 12). In order to correct the endogeneity of the R&D support variable, this variable is instrumented by its lagged value.

Reinthaler and Wolff (2004) analyzed the impact of subsidization (the ratio between government R&D subsidies and own financing) on R&D employment in the short and long terms using a panel data set of 15 OECD countries from 1981 to 2002. Reinthaler and Wolff concluded that an increase in the subsidization rate by 1 percentage point will lead to an additional 1% R&D employment in the long term, being the short-term effect lesser.[7]

As for the case of Finland, Ali-Yrkkö (2005) estimated the impact of public subsidies on firm's global (overseas) and domestic (national) R&D and other than R&D employment. Ali-Yrkkö used an instrument variable (IV) method in order to control the potential endogeneity of the public financing variable. However, it must be pointed out that the author did not correct wages endogeneity likewise.[8] This may

[6] See, for example, Suetens (2002), Reinthaler and Wolff (2004), Ali-Yrkkö (2005), Afcha and García-Quevedo (2016), Barajas et al. (2017), Dortet-Bernadet and Sicsic (2017), and Boeing et al. (2022).

[7] Reinthaler and Wolff pointed out that R&D employment (expressed in full-time equivalents) includes both researchers and those providing support to the researchers (secretaries, clerical staff…). Besides, using a sample for several OECD countries for the period 1980–2005, Thomson and Jensen (2010) find a positive effect of direct subsidies and tax incentives on the number of full-time equivalent R&D workers.

[8] See, for example, Marey and Borghans (2000), p. 16.

be the reason why the author obtained a positive sign for the coefficient corresponding to the variable defined as the quotient between the wage and the user cost of capital. Regarding the impact of public R&D financing, Ali-Yrkkö concluded that public financing has a positive and statistically significant effect on both domestic and global R&D employment.

Dortet-Bernadet and Sicsic (2017) investigate R&D subsidy impact on French R&D employment. The main result is that the effect of public R&D support on R&D employment is positive, although it is accompanied by a significant crowding-out effect. A similar result is obtained by Boeing et al. (2022) for the case of China. The authors state that "an increase in the R&D subsidy intensity by one standard deviation corresponds to a decrease of 6.46% in private R&D investments, but an increase of 2.57% in the R&D personnel employed" (p. 9). This observation is clear evidence in favor of a partial crowding-out effect of R&D subsidies on R&D inputs.

In a recent study for the British case, Ugur and Trushin (2018) conclude that the effect of subsidies on innovation inputs (one of these is R&D employment) is not uniform. For example, it is positive among start-ups and younger and smaller firms, but it could be negative during economic downturns and for older and larger firms.

As far as the Spanish case is concerned, Afcha and García-Quevedo (2016) used data from the *Technological Innovation Panel* for the period 2006–2011 and observed that R&D subsidies increased the number of R&D employees, but not the average R&D personnel skill level. Finally, Barajas et al. (2017) estimated the impact of participating in R&D support programs (CDTI) on some performance measures of Spanish firms before and after the beginning of the financial crisis.[9] One of these measures is a technological input computed as the ratio of R&D employment over total employment in the current year (the R&D personnel intensity). The authors concluded that participating in CDTI programs increased this ratio "by more than 4 percent both before and during the crisis, which points out the relevance of public financing in maintaining R&D human capital" (p. 15). In order to deal with potential endogeneity, the public funding variable was lagged one period in the estimates.

However, few authors have accurate information about the number of researchers at firms versus the rest of clerical staff (technicians and assistants) in order to estimate a labor demand function for researchers and to assess the impact of public R&D financing on this specific group of employees. A pioneer paper in this area is that by Goolsbee (1998), who analyzed the effects of government R&D spending on the labor conditions of scientists and engineers in the US and concluded that a significant share of this public funds goes directly into higher wages, since the supply of R&D employees is inelastic. As Goolsbee says, "income rises significantly while hours rise little" (p. 301).

On the other hand, Aerts (2008) estimated the impact of R&D grants on a group of variables, among which we can mention total R&D employment and the number of researchers, using data from the region of Flanders. Aerts concluded that the impact of public funding on R&D employment is very high: a subsidy of 1 million

[9] CDTI means Centre for the Development for Industrial Technology and it is the main public agency funding research in Spain.

euros would result in a hiring of 17.3 R&D full-time equivalent (FTEs) employees and 16.7 FTEs researchers.[10] That is, almost all additionally generated employment corresponds to researchers (versus technicians and assistants). In this sense, it must be stated that their estimates of the impact of public financing on total R&D employment and on researcher employment do not include wages as an explanatory variable, which makes it impossible to consider these estimates as true labor demand functions.

Finally, as for the case of Turkey, Taymaz and Üçdoğruk (2013) estimated a dynamic demand function for researchers using a sample of firms for period 1993–2001. Unlike many previous studies, their estimates have the advantage of including information about the wages of both researchers and staff, which are fundamental variables for a proper estimation of a labor demand function. Estimates correct the endogeneity of wages and of the support status variable by using an IV method. The outcomes state, for example, that the short run R&D support elasticity of demand for researchers is about 0.35 and the short run own wage elasticity is – 0.2.

Econometric Methodology and Data

In this research, we propose to estimate the following demand function:

$$\log L_{it} = \varphi_i + \gamma_t + \alpha \log W_{it} + \beta \log Y_{it} + \gamma M_{it} + \delta S_{it} + \mu_{it} \tag{1}$$

which is a static version of the common empirical model proposed, for example, by Taymaz and Üçdoğruk (2013), where L_{it} is the number of firm i researchers in time t, φ_i represents a specific firm effect that does not change over time, γ_t is a time effect that remains the same at all firms, W_{it} is the researchers' real wage, Y_{it} is the real output, M_{it} is the scope of the market served by the firm, S_{it} is the R&D public support variable, and μ_{it} is the error term. We will estimate this equation separately for industrial and services sectors because the technology features of each sector are rather different, as well as their innovation departments and the type of researchers hired in each case. For example, R&D staff hired by a steel company, industrial engineers mostly, is quite different from that hired by a telecommunications company, which will be IT engineers mainly

Data

The dataset used in this research is the *Technological Innovation Panel* (PITEC) carried out by the *Spanish Statistical Office* (INE) for the period 2004–2016. This dataset has a panel structure and provides information on the characteristics of

[10] Czarnitzki (2020) also observes that granting a subsidy has a positive effect on R&D employment for the case of Flanders.

thousands of Spanish firms, especially with regard to innovation.[11] Table 1 shows the definition of all variables used in estimates. Our dependent variable (*the log of the number of researchers*) is expressed in full-time equivalents. Regarding the independent variables, the dataset used herein allows knowing the *annual wage rate* of researchers. This is calculated by dividing the total annual remuneration of researchers by the number of researchers measured in full-time equivalents.[12] The Consumer Price Index published by INE [the *National Statistics Institute*] is used in order to deflate wages. On the other hand, PITEC does not provide information on firm's production, but it does provide that on *sales*, which is used as a proxy expressed in real terms. We used the Industrial Price Index to deflate sales in the case of industry, whereas the Consumer Price Index is used in the services sector (as the INE does not provide indexes of services prices before 2007).[13]

In relation to the scope of the market served by the firm (*European/global firm's market*), this feature is measured through a dummy variable that takes value 1 if the firm's market is European or worldwide and 0 in the rest of cases. The number of researchers is obviously expected to be higher at those European or global firms than at those local ones (which, therefore, moves in smaller and less competitive markets).

Finally, we will alternatively use two different types of variables to measure public R&D support. The first group (*public R&D financing over the past 3 years*) includes three dummy variables that take value 1 if the firm has received local/regional, national, or European public financing over the last 3 years, respectively. A firm could either accumulate one, two, or three types of financing simultaneously or have no public support at all (in this case, the three dummy variables will take zero values). As an alternative option, we replace the previous variables by a set of variables that show the origin of the research funds obtained in the current year by the firm (*origin of research funds obtained in the current year*). These variables are the percentage of firm R&D expenditures financed by own funds, by other firms, by public administrations, by universities, by private non-profit organizations, by the European Union, and by other foreign funds.

Tables 2 and 3 present descriptive statistics of the variables used in estimates. Table 2 only offers information of the subsample of firms hiring their own researchers (which are also those that carry out internal R&D in our case) during the 2004–2016 period. 31,299 observations of the industrial sector and 14,909 of the services sector are available. Unlike the previous one, Table 3 shows information related to all firms, whether they are hiring researchers or not, thus being 67,819 observations for industry and 54,000 for services. Based on these total samples, it will be possible to estimate a selection equation to find out how a firm is likely to decide to hire researchers. As it will be stated in the following section, estimating this selection equation is the first step of a procedure that will

[11] It is possible to access the dataset upon request at https://www.ine.es/infoine/.

[12] This is for instance the way that Lokshin and Mohnen (2008) and Tamayo and Huergo (2016) computed R&D employees' wages.

[13] In this sense, Marey and Borghans (2000) also use the Consumer Price Index (CPI) to deflate wages and the Production Price Index (PPI) to deflate the rest of variables when estimating the impact of R&D expenditure on total R&D employment in the Netherlands.

Table 1 Variable definitions

Dependent variables	
Log of the number of researchers	Natural logarithm of the number of researchers working at the firm expressed in full-time equivalents (it is the addition of researchers who work full-time plus the share of time of R&D part-time researchers)
Independent variables	
Log of researchers' real wage	Natural logarithm of annual earnings of all firm's researchers divided by the number of researchers measured in full-time equivalents. We use the Consumer Price Index to deflate
Log of real sales	Natural logarithm of sales measured in real terms. We use the Industrial Price Index to deflate in case of the industrial sector. We use the Consumer Price Index in case of the services sector, since the Spanish Statistical Office (INE) only provides information about prices in services from 2007 onwards
European/global firm's market	Dummy variable that takes value 1 if the firm's market is European or worldwide and 0 in the rest of the cases
Public R&D financing over the past 3 years	
Local/regional public financing	Dummy variable that takes value 1 if the firm has received public financing from local or regional authorities over the past 3 years and 0 in the rest of the cases
National public financing	Dummy variable that takes value 1 if the firm has received public financing from national authorities over the past 3 years and 0 in the rest of the cases
EU public financing	Dummy variable that takes value 1 if the firm has received public financing from European authorities over the past 3 years and 0 in the rest of the cases In all the above-referred cases, this includes financing through tax credits or deductions, grants, subsidized loans, and loan guarantees. Research and other innovation activities, entirely carried out by contract for the public sector, are excluded
Origin of research funds obtained in the current year	
R&D financing: own funds	Proportion of firm R&D expenditures financed by own funds. Repayable loans received from the public administration or other financial institutions are considered as own funds (see, PITEC, 2016)
R&D financing: other firms	Proportion of firm R&D expenditures financed by other firms
R&D financing: public sector	Proportion of firm R&D expenditures financed by public administrations

Table 1 (continued)

Dependent variables	
R&D financing: universities	Proportion of firm R&D expenditures financed by universities
R&D financing: non-profit organizations	Proportion of firm R&D expenditures financed by private non-profit organizations
R&D financing: European Union	Proportion of firm R&D expenditures financed by the European Union
R&D financing: other foreign funds	Proportion of firm R&D expenditures financed by other foreign funds
Variables included only in the selection equation	
Hiring researchers	Dummy variable that takes value 1 if the company hires researchers and 0 if it does not. In our sample, all firms that hire researchers are internal R&D performers
Firm's real investment	Firm's investment measured in real terms. We use the Industrial Price Index to deflate in case of the industrial sector. We use the Consumer Price Index in case of the services sector
High and medium–high technological firm	Dummy variable that takes value 1 if the industrial company may be considered as a high or medium–high (HMH) technological firm and 0 if it is a low or medium–low (LML) tech firm
Knowledge-intensive services firm	Dummy variable that takes value 1 if the services company may be considered as a knowledge-intensive services firm (KIS) and 0 if it is a non-knowledge-intensive services firm (NKIS)

allow correcting sample selection bias. For this reason, Table 3 includes some additional variables which were not included in Table 2 and which are essential to be able to estimate such equation. These variables, whose definitions also appear in Table 1, are *hiring researchers*, *firm's real investment*, *high and medium–high technological firm*, and *knowledge-intensive services firm.*

It is important to point out some interesting features of the samples used in this research. On the one hand, Table 2 data show that the average number of researchers is greater in case of services sector firms in spite of having fewer sales than industrial firms. On the other hand, the average wage rate is lower in the services sector, both in case of researchers and in case of technicians and assistants. This feature may be related to the higher percentage of female employment in this sector (39.3% versus 26.5% in the industrial sector). Besides, market scope is much wider in case of industry, as 88.2% of industrial firms supply European or worldwide markets, compared to 54.1% in case of the services sector. In relation to R&D expenditure financing, there are significant differences as the percentage of firms receiving public R&D financing is greater in the services sector than in the industrial one. Particularly, the percentage of firms receiving local or regional public financing is 40.4% in case of services versus 31% in case of industry. A

Table 2 Variable descriptive statistics. Subsamples of firms hiring their own researchers. Period: 2004–2016. Source: PITEC

Variable	Industry		Services	
	Mean	S. dev	Mean	S. dev
Log of the number of researchers	0.366	1.331	0.740	1.553
Log of real sales	16.644	1.735	15.425	2.319
Log of researchers' real wage	10.840	0.561	10.745	0.568
Log of technicians and assistants' real wage	10.441	0.569	10.373	0.579
Proportion of female employment	0.265	0.194	0.393	0.212
European/global firm's market	0.882	0.323	0.541	0.498
Local/regional public financing	0.310	0.463	0.404	0.491
National public financing	0.346	0.476	0.444	0.497
EU public financing	0.071	0.257	0.200	0.400
R&D financing: own funds	0.886	0,232	0.731	0,350
R&D financing: other firms	0.008	0.075	0.040	0.152
R&D financing: public sector	0.090	0.198	0.182	0.274
R&D financing: universities	0.0003	0.011	0.001	0.019
R&D financing: non-profit organizations	0.001	0.170	0.003	0.039
R&D financing: European Union	0.008	0.070	0.032	0.122
R&D financing: other foreign funds	0.006	0.072	0.011	0.084
2004	0.095	0.292	0.086	0.281
2005	0.111	0.314	0.120	0.325
2006	0.102	0.302	0.103	0.305
2007	0.096	0.295	0.097	0.295
2008	0.087	0.282	0.090	0.286
2009	0.079	0.270	0.081	0.273
2010	0.073	0.261	0.077	0.266
2011	0.069	0.253	0.070	0.255
2012	0.065	0.246	0.067	0.251
2013	0.061	0.240	0.059	0.236
2014	0.057	0.232	0.053	0.223
2015	0.054	0.226	0.051	0.219
2016	0.051	0.219	0.046	0.208
Number of observations		31,299		14,909

similar difference is observed in the percentage of firms receiving national public financing (44.4% versus 34.6%). However, a greater difference is observed in the percentage of firms receiving European public funds (20% in services versus 7.1% in the industrial sector). In relation to the origin of the funds allocated to R&D, it is worth noting that most of the funds devoted to R&D by firms come from their own funds (specifically, 88.6% in the case of industry and 73.1% in the case of services). Only 9.8% of these funds in the case of industry and 21.6% in

Table 3 Variable descriptive statistics for the total samples. Period: 2004–2016. Source: PITEC

	Industry		Services	
Variable	Mean	S. dev	Mean	S. dev
Hiring researchers	0.566	0.496	0.381	0.486
Log of real sales	16.102	1.885	15.660	2.415
European/global firm's market	0.785	0.411	0.407	0.491
Local/regional public financing	0.198	0.399	0.166	0.372
National public financing	0.198	0.398	0.173	0.378
EU public financing	0.041	0.199	0.074	0.262
Firm's real investment	4.05e+06	5.87e+07	7.01e+06	8.11e+07
High and medium–high technological firm	0.422	0.494	–	–
Knowledge-intensive services firm	–	–	0.710	0.453
R&D financing: own funds	0.504	0.475	0.284	0,419
R&D financing: other firms	0.004	0.056	0.014	0.092
R&D financing: public sector	0.049	0.155	0.067	0.189
R&D financing: universities	0.0002	0.012	0.0004	0.013
R&D financing: non-profit organizations	0.0003	0.013	0.001	0.022
R&D financing: European Union	0.005	0.053	0.012	0.077
R&D financing: other foreign funds	0.003	0.053	0.003	0.049
2004	0.080	0.271	0.076	0.265
2005	0.095	0.293	0.092	0.289
2006	0.095	0.293	0.092	0.289
2007	0.091	0.288	0.088	0.284
2008	0.087	0.282	0.086	0.280
2009	0.084	0.278	0.083	0.276
2010	0.080	0.272	0.081	0.273
2011	0.077	0.267	0.078	0.269
2012	0.073	0.261	0.077	0.266
2013	0.070	0.255	0.073	0.261
2014	0.055	0.227	0.056	0.231
2015	0.053	0.224	0.055	0.229
2016	0.059	0.236	0.061	0.239
Number of observations		67,819		54,000

that of services come from either public administrations or the European Union (that is, they are public R&D subsidies).

Finally, an interesting feature can be referred to by focusing on the information provided by Table 3 (corresponding to both firms hiring researchers and those that do not): the percentage of industrial firms hiring researchers is much higher than in case of the services sector firms (56.6% versus 38.1%). As for the rest of variables, it should be noted that the fact of including in the sample those firms that do not hire researchers makes variables that show the relevance of public R&D support take smaller mean values than those observed in Table 2.

Empirical Results

Tables 4, 5, 6, and 7 show estimates of the demand function for researchers for the industrial and services sectors. Two alternative estimation methods have been used. Firstly, we estimate a Two-Stage Least Squares (2SLS) fixed-effect model for the period 2004–2016 using only the information provided by the subsample of firms hiring their own researchers (see Tables 4 and 5).[14] This procedure allows controlling unobserved heterogeneity and eliminating fixed effects by taking first differences. At the same time, we may control for the endogeneity of the wage variable by using instrumental variables (IV). As Marey and Borghans (2000) pointed out, there are several reasons to expect the presence of an endogeneity bias when estimating a function such as this one: identification problems, the problem of non-stationarity of macroeconomic regressors, and, mainly, the way researchers' average wage rate is computed. Average wage rate is defined as the total labor cost of researchers divided by the number of FTE researchers. The number of FTE researchers is the variable to be explained, while also being the denominator of one of the explanatory variables (average wage rate). Therefore, increases in the number of researchers lead to increases in the value of the dependent variable and, simultaneously, reductions of the average wage rate, thus generating a spurious negative correlation that causes a negative division bias (Marey & Borghans, 2000, p.16). In order to correct wages' endogeneity, this variable is instrumented by other two. First is the *log of technicians and assistants' real wage* that is proportionally related to researchers' real wage and it also evolves quite symmetrically.[15] Second is the *proportion of female employment*, as a higher proportion of women will be supposed to lead the firm to reach lower average wages, including that of researchers assuming the presence of wage discrimination.

However, wages are not the only endogenous variable in this type of models. Public R&D subsidies may boost the demand for researchers. However, as Suetens (2002) and Ali-Yrkkö (2005) point out, it is also true that those firms with a higher number of researchers (or those spending more on R&D) are more likely to obtain this type of funds. Therefore, all variables representing R&D support have been lagged one period in order to control for endogeneity of public R&D financing, as, for example, Suetens (2002) and Barajas et al. (2017) did. The set of instruments also includes all exogenous variables.

Tables 4 and 5 display estimate outcomes. Columns (a) and (b) correspond to the sample of industrial firms and columns (c) and (d) to the sample of services firms. On the other hand, public support for R&D is measured in (a) and (c) estimates as the proportion of firms' R&D expenditure financed by public administrations or the European Union. Estimates also include other dummy variables that allow fully identifying the origin of all the funds devoted to research (other

[14] We use *xtivreg2* STATA command (see Schaffer, 2010), being standard errors robust to heteroskedasticity.

[15] This variable is defined as the log of annual earnings of all firm's technicians and assistants divided by the number of technicians and assistants measured in full-time equivalents. We use the Consumer Price Index to deflate.

Table 4 Demand function for researchers (IV/Two-Stage Least Squares estimation). Industry. Period: 2004–2016

Independent variables	Dependent variable: log of the number of researchers			
	(a)		(b)	
	Coefficient	*z*	Coefficient	*z*
Log of real sales	0.160	10.24**	0.158	11.15**
Log of researchers' real wage[a]	−0.534	−17.89**	−0.539	−18.10**
European/global firm's market_1	0.042	1.34	0.040	1.25
Local/regional public financing_1	–	–	0.065	5.02**
National public financing_1	–	–	0.094	7.35**
EU public financing_1	–	–	0.070	2.99**
R&D financing: other firms_1	0.050	0.71	–	–
R&D financing: public sector_1	0.059	1.89*	–	–
R&D financing: universities_1	0.062	0.18	–	–
R&D financing: non-profit organizations_1	−0.187	−0.60	–	–
R&D financing: European Union_1	0.110	1.15	–	–
R&D financing: other foreign funds_1	0.131	1.07	–	–
2006	−0.006	−0.34	−0.008	−0.41
2007	−0.045	−2.39**	−0.041	2.17**
2008	0.006	0.32	0.013	0.66
2009	0.062	3.11**	0.067	3.38**
2010	0.079	3.86**	0.083	4.10**
2011	0.091	4.39**	0.096	4.65**
2012	0.078	3.67**	0.084	3.98**
2013	0.066	3.01**	0.078	3.54**
2014	0.042	1.84*	0.056	2.43**
2015	0.050	2.12**	0.054	2.28**
2016	0.083	3.24**	0.084	3.29**
$F(20; 22{,}511)$		22.28		–
$F(17; 22{,}514)$		–		31.65
Hansen J statistic χ^2 (1)		1.046		1.217
Kleibergen-Paap rk LM χ^2 (2)		737.510		736.773
Kleibergen-Paap rk Wald F		821.190		820.910
Endogeneity test for real wage χ^2 (1)		50.269		52.721
Number of observations		26,438		26,438

[a]Instrumented variable. Excluded instruments: *log of technicians and assistants' real wage; proportion of female employment.* Statistics robust to heteroskedasticity

** and * represent significance at the 5% and 10% level, respectively

Table 5 Demand function for researchers (IV/Two-Stage Least Squares estimation). Services. Period: 2004–2016

	Dependent variable: log of the number of researchers			
	(c)		(d)	
Independent variables	Coefficient	*z*	Coefficient	*z*
Log of real sales	0.156	10.17**	0.152	10.08**
Log of researchers' real wage[a]	−0.576	−11.72**	−0.579	−11.81**
European/global firm's market_1	0.072	2.67**	0.065	2.43**
Local/regional public financing_1	–	–	0.132	5.63**
National public financing_1	–	–	0.156	6.85**
EU public financing_1	–	–	0.079	2.66**
R&D financing: other firms_1	0.050	0.68	–	–
R&D financing: public sector_1	0.199	4.58**	–	–
R&D financing: universities_1	0.907	2.64**	–	–
R&D financing: non-profit organizations_1	0.005	0.02	–	–
R&D financing: European Union_1	−0.010	−0.09	–	–
R&D financing: other foreign funds_1	0.350	2.80**	–	–
2006	−0.003	−0.10	−0.003	−0.10
2007	0.080	2.39**	0.090	2.70**
2008	0.139	4.03**	0.144	4.18**
2009	0.140	3.98**	0.139	3.98**
2010	0.131	3.69**	0.131	3.72**
2011	0.103	2.84**	0.109	3.03**
2012	0.098	2.63**	0.101	2.72**
2013	0.115	2.92**	0.120	3.06**
2014	0.127	3.14**	0.126	3.13**
2015	0.085	1.99**	0.075	1.76*
2016	0.124	2.70**	0.108	2.36**
$F(20; 9980)$		14.73		–
$F(17; 9983)$		–		20.48
Hansen J statistic χ^2 (1)		0.561		0.637
Kleibergen-Paap rk LM χ^2 (2)		504.536		503.770
Kleibergen-Paap rk Wald F		521.873		521.547
Endogeneity test for real wage χ^2 (1)		11.235		11.340
Number of observations		12,060		12,060

[a]Instrumented variable. Excluded instruments: *log of technicians and assistants' real wage; proportion of female employment.* Statistics robust to heteroskedasticity

** and * represent significance at the 5% and 10% level, respectively

Table 6 Demand function for researchers (correcting for sample selection bias and endogeneity). Industry. Period: 2004–2016

	Dependent variable: log of the number of researchers			
	(e)		(f)	
Independent variables	Coefficient	*z*	Coefficient	*z*
Log of real sales	0.203	6.06**	0.201	6.98**
Log of researchers' real wage[a]	−0.594	−6.61**	−0.603	−8.38**
European/global firm's market	0.077	1.33	0.082	1.53
Local/regional public financing_1	–	–	0.068	2.23**
National public financing_1	–	–	0.091	3.20**
EU public financing_1	–	–	0.057	1.49
R&D financing: other firms_1	0.049	−0.39	–	–
R&D financing: public sector_1	0.095	1.75*	–	–
R&D financing: universities_1	−0.145	−0.39	–	–
R&D financing: non-profit organizations_1	−0.272	−0.25	–	–
R&D financing: European Union_1	0.202	1.20	–	–
R&D financing: other foreign funds_1	0.110	−0.15	–	–
2006	0.061	0.41	0.053	0.29
2007	0.209	1.09	0.407	2.52**
2008	0.263	1.29	0.245	0.98
2009	0.248	0.96	0.202	0.79
2010	0.478	1.80*	0.529	1.72*
2011	0.412	1.58	0.603	1.97**
2012	0.789	2.94**	0.737	2.70**
2013	0.655	2.30**	0.463	1.62
2014	0.753	2.60	0.427	1.43
2015	0.636	1.97**	0.537	1.69*
2016	0.322	1.10	0.089	0.34
2005*IMR	−0.130	−0.55	−0.204	−0.91
2006*IMR	−0.267	−1.11	−0.308	−0.99
2007*IMR	−0.518	−1.81*	−0.842	−3.23**
2008*IMR	−0.463	−1.66*	−0.495	−1.59
2009*IMR	−0.387	−1.27	−0.389	−1.32
2010*IMR	−0.600	−2.12**	−0.726	−2.06**
2011*IMR	−0.551	−1.99**	−0.858	−2.30**
2012*IMR	−1.050	−3.53**	−1.062	−3.18**
2013*IMR	−0.847	−3.02**	−0.687	−2.04**
2014*IMR	−1.031	−3.01**	−0.833	−1.68*
2015*IMR	−0.814	−2.22**	−0.773	−1.95*
2016*IMR	−0.396	−1.14	−0.199	−0.59
Constant	−2.487	−2.54**	−1.241	−1.46
Bootstrap replications		50		50
Number of observations		27,101		27,101

[a]Instrumented variable. *IMR* inverse Mills ratio. Excluded instruments: *log of technicians and assistants' real wage; proportion of female employment.*Selection equation estimation outcomes are not displayed here but are available for consultation.

** and * represent significance at the 5% and 10% level, respectively.

Table 7 Demand function for researchers (correcting for sample selection bias and endogeneity). Services. Period: 2004–2016

	Dependent variable: log of the number of researchers			
	(g)		(h)	
Independent variables	Coefficient	z	Coefficient	z
Log of real sales	0.158	7.76**	0.150	8.21**
Log of researchers' real wage[a]	−0.537	−7.88**	−0.537	−8.81**
European/global firm's market	0.077	2.32**	0.072	1.81*
Local/regional public financing_1	–	–	0.145	4.57**
National public financing_1	–	–	0.155	5.01**
EU public financing_1	–	–	0.091	2.86**
R&D financing: other firms_1	0.041	0.46	–	–
R&D financing: public sector_1	0.238	3.76**	–	–
R&D financing: universities_1	0.862	2.05**	–	–
R&D financing: non-profit organizations_1	0.051	0.13	–	–
R&D financing: European Union_1	−0.023	−0.13	–	–
R&D financing: other foreign funds_1	0.367	2.58**	–	–
2006	−0.035	−0.50	0.018	0.32
2007	0.029	0.37	0.107	1.75*
2008	0.043	0.71	0.172	2.86**
2009	0.083	1.17	0.206	3.30**
2010	0.053	0.66	0.137	2.06**
2011	0.124	1.26	0.172	2.46**
2012	0.097	1.20	0.159	2.37**
2013	0.105	1.20	0.201	2.28**
2014	0.034	0.40	0.144	1.81*
2015	0.074	0.80	0.161	1.69*
2016	0.114	1.04	0.145	1.60
2005* IMR	−0.815	−2.23**	0.068	0.22
2006*IMR	−0.739	−2.70**	0.050	0.17
2007*IMR	−0.776	−2.40**	−0.028	−0.11
2008*IMR	−0.442	−1.51	0.089	0.36
2009*IMR	−0.493	−1.84*	0.001	0.00
2010*IMR	−0.299	−0.98	0.311	1.24
2011*IMR	−0.709	−2.05**	0.046	0.19
2012*IMR	−0.731	−2.33**	−0.023	−0.10
2013*IMR	−0.519	−1.76*	0.004	0.02
2014*IMR	−0.180	−0.60	0.267	1.04
2015*IMR	−0.316	−1.08	0.158	0.52
2016*IMR	−0.429	−1.32	0.219	0.94
Constant	0.752	0.84	0.623	0.77
Bootstrap replications		50		50
Number of observations		12,600		12,600

[a]Instrumented variable. *IMR* inverse Mills ratio. Excluded instruments: *log of technicians and assistants' real wage; proportion of female employment.* Selection equation estimation outcomes are not displayed here but are available for consultation.

** and * represent significance at the 5% and 10% level, respectively.

firms, universities, non-profit organizations, etc.). Alternatively, in case of (b) and (d) estimates, public R&D support is measured by means of three dummy variables that show whether the firm has received local, national, or European public funds over the past 3 years.

The values of the Hansen J statistics (an overidentification test of all instruments) show the quality of estimates, where the validity of overidentifying restrictions is the null hypothesis. Its values are 1.046 ($p=0.306$), 1.217 ($p=0.270$), 0.561 ($p=0.454$), and 0.637 ($p=0.425$) for (a), (b), (c), and (d) estimates, respectively. Therefore, we should not reject the null hypothesis. Estimates also display the Kleibergen-Paap rk LM statistics (a test to know whether the model is underidentified), where the null hypothesis is that the excluded instruments are not correlated with the endogenous regressor. Instruments will be valid if the null hypothesis is rejected. Since the values of this test are 737.510 ($p=0.000$), 736.773 ($p=0.000$), 504.536 ($p=0.000$), and 503.770 ($p=0.000$), the null hypothesis is rejected.[16]

Two particularly interesting parameters are the elasticities of the demand for researchers with respect to output and wages.[17] It is important to point out that regardless of the way to measure public R&D support, the former takes an approximate 0.16 value and the latter − 0.53 in the case of the industrial sector (0.15 and − 0.58 as for the services sector). That is, 1% increase of researchers' real wage shall cause researchers' demand decrease between 0.53 and 0.58%, depending on the sector.[18] The decrease is greater in the services sector. On the other hand, 1% increase in real sales shall raise researchers' demand between 0.16 and 0.15%, with no remarkable difference between both sectors.[19]

In the second place, the firm's market scope is a very significant variable in case of services. It seems that selling in European or worldwide markets is a factor that boosts firms' demand for researchers. However, this variable is not significant in the industrial sector case.

As far as the origin of the R&D funds is concerned (a and c estimates), note that the coefficients of these variables show to what extent having any of the different types of R&D funding affects the employment of researchers compared to the impact of the excluded category (which is the percentage of own funds). It is observed that given the reference category, the demand for researchers in the industrial sector grows significantly only when the proportion of public funds increases. However, the proportion of firm R&D expenditure financed by universities and by

[16] Besides, an endogeneity test has been carried out for the real wage variable. This test is distributed as a χ^2 with one degree of freedom, where the null hypothesis is that researchers' real wage is exogenous. The values of these tests are 50.269 ($p=0.000$), 52.721 ($p=0.000$), 11.235 ($p=0.000$), and 11.340 ($p=0.000$), respectively. So, the null hypothesis is rejected ant it may be stated that researchers' real wage is an endogenous variable.

[17] Given that these variables (number of researchers, wages, and output) are expressed in logarithms, their estimated coefficients shall be interpreted as the elasticities of the demand for researchers with respect to wages and output, respectively.

[18] For comparison purposes, in the Turkish case, Taymaz and Üçdoğruk (2013) obtained own wage elasticities between − 0.2 (short term) and − 0.5 (long term).

[19] This value is similar to that obtained by Taymaz and Üçdoğruk (2013) in the short term (specifically, 0.13) and higher than that calculated by Tamayo and Huergo (2016) (between 0.05 and 0.09).

other sources is also significant in the services sector. It must be remembered that these variables have been lagged one period. In short, outcomes show that as the intensity of public R&D support increases, the demand for researchers grows significantly both for industry and services sectors.

If a new set of dummy variables are included to identify whether public support comes from a local/regional, national, or European funder (b and d estimates) instead of considering the origin of all research funds, we observe that these variables are always significant.[20] That is, receiving financing through tax credits or deductions, grants, subsidized loans, and loan guarantees coming from local, national, or European authorities as opposed to not receiving public R&D support has a positive and strong impact on researchers' employment. Moreover, the effect of these supports is much more intense in the case of services and, especially, when they come from a national authority. To be precise, in this latter case, it can be stated that the fact of getting national public R&D funds increases the demand for researchers by 16.8% in the case of services firms (versus 9.8% in the industrial sector).[21]

Finally, the impact of annual dummies is generally significant and positive (being the reference year 2005). Since 2009, and in spite of the economic crisis, the demand for researchers is greater than the corresponding one in 2005. That is, given a scenario of uncertainty when demand is falling, it seems that Spanish firms have bet on keeping and even increasing their research teams to keep up with competitiveness.

As stated above, estimates shown in Tables 4 and 5 only use data from the subsamples of firms hiring researchers, whose wages are the only ones we know. At the same time, these firms are those that spend on internal R&D. As we have already mentioned, only 56.6% of total sample firms from the industrial sector and 38.1% from the services sector hire researchers. This means that the subsamples used in such estimates may not be at random, which would imply the existence of a selection bias affecting the quality of the estimates.[22] For this reason, the model has been alternatively estimated using the STATA *xtheckmanfe* command, developed by Ríos-Ávila (2020).[23] This command is appropriate to estimate panel data models in the presence of endogeneity and selection and use the information of all sample firms (either those hiring researchers or those that do not). At a first stage, the procedure consists on estimating a selection equation where the variable to be explained, called *hiring researchers*, is a dummy that takes value 1 if the firm hires researchers and 0 if not. In order to explain such decision, two new variables are included in addition

[20] Both groups of variables are separately incorporated in estimates in order to make the most of the information provided by the sample without causing multicollinearity problems that could come up should these two ways of measuring the public support were considered simultaneously.

[21] The former outcomes are in line with the obtained previously, for example, by Reinthaler and Wolff (2004), Ali-Yrkkö (2005), Dortet-Bernadet and Sicsic (2017), and Boeing et al. (2022) for different European countries and for the case of China and by Afcha and García-Quevedo (2016) and Barajas et al. (2017) for the Spanish case. All of them generally show a positive effect of public R&D subsidies on R&D employment, although the intensity of this effect varies greatly.

[22] Three examples of sample selection bias correction for this type of estimation are Barajas et al. (2017), Huergo and Moreno (2017), and Busom (2000).

[23] This command is inspired in the model proposed by Semykina and Wooldridge (2010) and is based on the dofile written by Anastasia Semykina for the two-step parametric approach (see http://myweb.fsu.edu/asemykina/).

to the variables considered in Tables 4 and 5. First of all, the *firm's real investment*, as it is supposed that the more the firm invests in capital, the higher the likelihood of spending on internal R&D, and so of hiring researchers. Secondly, it is assumed that the likelihood of hiring internal researchers is greater in those highly technological activity branches, both in industrial and services sectors. It is for this reason that the industrial sector estimate includes a new variable named *high and medium–high technological firm* (a dummy variable that takes value 1 if the industrial firm is to be considered as a high or medium–high (HMH) technological firm and 0 if it is a low or medium–low (LML) tech firm). On the other hand, in the case of services sector estimate, variable *knowledge-intensive services firm* is included (a dummy variable that takes value 1 if the firm is to be considered as a knowledge-intensive services firm (KIS) and 0 if it is a non-knowledge-intensive services firm (NKIS)). We use the criteria proposed by Goya et al. (2016) to consider a specific branch of industry (services) as HMH (KIS) tech (see Tables 8 and 9 of the Appendix).

Once the selection equation has been estimated, the second stage of this procedure consists on estimating a demand function for researchers using only the data of those firms hiring researchers. The endogenous variables are instrumented as it was previously done. In short, this estimate method allows correcting two bias simultaneously: the sample selection bias of firms hiring researchers and the endogeneity bias of average wages and public R&D financing variables. The results of this second stage estimates are displayed in Tables 6 and 7.[24]

Comparing estimate results for the industrial sector (Table 6) with the previous ones (Table 4), we observe that the elasticities of the demand for researchers with respect to output and wages slightly increase (in the latter case, in absolute value). They are now 0.20 and − 0.60, approximately, regardless of how public R&D financing impact is measured. As far as the impact of public R&D financing is concerned, the most relevant change is that the European financing dummy is no longer significant (f estimate). In relation to the services sector estimates (Table 7), a slight reduction in the elasticity of the demand for researchers with respect to wages (absolute value reduced to − 0.537) is the only remarkable change compared to Table 5. Finally, to account for sample selection, the model includes the interactions of the inverse Mills ratios (IMR) with time variables. Their coefficients are significant and negative in general, except in (h) estimate corresponding to services.The significance and negative sign of interactions of annual dummies with the IMR mean that there is a "negative selection" so that, if the correction for the selection bias had not been applied, the estimated coefficients would be downward-biased. In this sense, we may conclude that, although the differences between the two estimate methodologies do not produce very different results, Tables 6 and 7 estimates are the ones presenting the most reliable coefficients.

[24] The *xtheckmanfe* estimate procedure includes a great number of interactions between the model variables and the annual dummies in the first stage, which enormously increase the number of estimated coefficients. For such reason, we have decided not to present the results herein, although they are available for consultation.

Conclusions

This research has assessed the impact of R&D subsidies on the demand for researchers in Spanish firms based on the estimation of a labor demand function that uses information from a panel of firms followed up during the period 2005–2016. The estimation of this type of labor demand function presents some specific features. First of all, both the fact of receiving public R&D subsidies and the wage of researchers are endogenous variables so that they need to be instrumented in order to correct endogeneity bias. Secondly, it is only possible to know researchers' wages in case of firms that decided to carry out internal R&D (they represent 56.6% of industrial firms and 38.1% of services firms in our sample); thus, estimating a demand function for researchers just for this firm subsample may cause a selection bias to be considered. Therefore, an accurate estimation of the model requires choosing an estimate method that allows correcting both types of bias simultaneously. Although this type of research does usually apply the correction for the sample selection bias and for the endogenous nature of public R&D support, there are no prior estimates in the Spanish case that also take the endogenous nature of wages into account. This is one of the contributions of this research.

On the other hand, the way of measuring public support to innovation varies greatly depending on the type of study (loan, subsidy, tax credit…). In our case, the dataset used has made it possible to measure the public financing received by firms in two alternative ways. The first one is, in a qualitative way, by including the fact of having received tax credits, loans, and grants from local/regional, national, or European authorities in the last 3 years as an explanatory variable. The second one is, in a quantitative way, by considering the proportion of firm R&D expenditures financed by the public sector or the European Union in the estimates. This has allowed us to test the stability of the results, which constitutes a second relevant contribution of the research.

Regarding the main results, the impact of public R&D financing on the demand for researchers has been found to be positive and very significant, regardless of the public financing indicator used. On the one hand, the fact of receiving public financing (tax credits, loans, and grants) from local/regional, national, or European entities stimulates the employment of researchers (except for the case of European funding in the industry sector). On the other hand, in relation to the origin of the funds that firms devote to research, we see that, for both sectors, the higher the percentage of the total R&D expenditures financed by the public administration (compared to the expenditures financed by their own funds), the higher the employment of researchers. These outcomes are similar to those obtained by Afcha and García-Quevedo (2016) and Barajas et al. (2017) for the Spanish case.

These results have clear policy implications. Since scientist and researchers contribute in a very relevant way to innovations and patents, public research financing policies should be extended as much as possible, because there is a positive and highly significant impact of such policies on the employment of researchers as it has been observed. Such positive impacts are likely to be turned into higher innovating capacity and higher productivity of Spanish firms at a later stage. However, the government should not only contribute to increasing the employment of researchers through tax credits, subsidies, or loans granted to firms. It should also play a prominent role in increasing the supply of researchers by improving the Spanish higher education system (mostly public) through greater financing for research teams and for the training of new researchers.[25] Recent data are extremely clarifying: only two Spanish universities are among the world's top 300 in 2023, according to the "Academic Ranking of World Universities" (ARWU), known as the "Shanghai ranking."[26] The ranking considers the following criteria among others: the number of highly cited researchers selected by Clarivate, the number of articles published in Nature and Science, and the number of articles indexed in the Science Citation Index and the Social Sciences Citation Index. Undoubtedly, the availability of a greater supply of high-quality researchers would encourage firms to increase their demand, thus generating more and better innovation.

Regarding the limitations of this study and the likelihood of extending it into the future, we must bear in mind that the analyzed period ends in 2016. Since then, technological change has rocketed and ICT advances have increasingly influenced production methods, especially after the COVID-19 crisis. Important advances have taken place during the last 7 years in the fields of artificial intelligence, the Internet of Things, robotization, and renewable energies for example. Therefore, it would be interesting to replicate this type of analysis with more updated data. In such case, the above-referred technological advances would make it increasingly necessary to promote research and so to apply public policies to stimulate hiring researchers and innovation at firms as much as possible.

[25] Some specific policies that can be developed at the national level have already been successfully implemented at the regional level. This is the case of Ikerbasque, the Basque Foundation for Science. It was created in 2007 by the Basque Regional Government to strengthen the Basque Science System. The novelty of this policy consists of the hiring of promising researchers and young research leaders from around the world, to work in the universities and research centers of the Basque Country with their own projects and objectives. These researchers have published more than 9000 articles in indexed journals and have obtained more than 235 million euros in research projects. These economic resources are invested in equipment and laboratories to promote new research (see https://www.ikerbasque.net/en/about-us). It should be noted that R&D expenditure as a percentage of GDP reached 2.32% in the Basque Country in 2021, compared to 1.43% in the case of Spain (see INE, 2021). This gap is very stable over time and could be one of the reasons why the unemployment rate in the Basque Country is significantly lower than in Spain (9.8% compared to 14.8% in 2021).

[26] See https://www.shanghairanking.com/rankings/arwu/2023.

Appendix

Table 8 Branches of industry (correspondence between PITEC before 2008 and PITEC in 2008 and after)

High and medium–high technological firms		Low and medium–low technological firms	
PITEC before 2008	PITEC 2008 and after	PITEC before 2008	PITEC 2008 and after
Coke ovens and oil refining	Oil refining	Extractive industries	Extractive industries
Chemical products (except pharmaceuticals)	Chemical products	Food and beverages	Food, beverages, and tobacco
Pharmaceutical products	Pharmaceutical products	Tobacco	
Machinery and equipment	Manufacturing	Textile products	Textile products
Office machinery and computers		Clothing and furriers	Clothing
Electrical machinery and apparatus	Electrical machinery, computers, electronic, and optical instruments	Leather and footwear	Leather and footwear
Electronic components		Wood and cork	Wood and cork
Radio, TV, and communication equipment		Paper products	Carton and paper
Medical and optical instruments, watches, clocks		Publishing and printing	Publishing and printing
Motor vehicles	Motor vehicles	Rubber and plastic products	Rubber and plastic products
Aircraft and spacecraft	Aircraft and spacecraft	Tiles and ceramic tiles	
Other transport equipment	Other transport equipment	Non-metallic mineral products	Non-metallic mineral products
Production of electricity, gas and water	Energy and water	Ferrous metallurgic products	Metallurgic products
	Repair and installation of machinery and equipment	Non-ferrous metallurgic products	
		Metal products (except machinery and equipment)	
		Ship building	Ship building
		Furniture	Furniture
		Games and toys	
		Other manufactures	Other manufactures

Table 8 (continued)

High and medium–high technological firms		Low and medium–low technological firms	
PITEC before 2008	PITEC 2008 and after	PITEC before 2008	PITEC 2008 and after
		Recycling	
			Other machinery and equipment
			Sanitation, waste management, and decontamination

Source: Goya et al. (2016)

Table 9 Branches of services (correspondence between PITEC before 2008 and PITEC in 2008 and after)

Knowledge-intensive services firms		Non-knowledge-intensive services firms	
PITEC before 2008	PITEC 2008 and after	PITEC before 2008	PITEC 2008 and after
Post		Sales and repair of motor vehicles	
Telecommunications	Telecommunications	Wholesale trade	Trade
Financial intermediation	Financial intermediation	Retail trade	
Real estate activities	Real estate activities	Hotels and restaurants	Hotels and restaurants
Renting of machinery and equipment		Transport	Transport
Computer activities	Computer activities	Supporting and auxiliary transport activities, travel agencies	
Other related computer activities	Other related computer activities		
Research and development	Research and development		
Architectural and engineering activities			
Technical testing and analysis			
Other business activities	Other business activities		
Education	Education		
Motion picture, video, and television program production	Arts and entertainment activities		
Programming and broadcasting activities			
Other human health and social activities	Health and social activities		
	Other activities		
	Other services		

Source: Goya et al. (2016)

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Declarations

Competing Interests The authors declare no competing interests.

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