ABSTRACT

Title: Growing like Spain: Effects of EU Regional Policy on Productivity (1989-2010)

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Abstract:
Total Factor Productivity (TFP) in Spain over 1989-2010 has followed a decreasing trend. This paper examines to what degree research and development (RD) expenditures and the investments in transport infrastructure supported by the EU regional and cohesion policy (EUINFP) prevent TFP over this period from falling further. Using an augmented Mankiw-Romer-Weil (1992) model we derive an econometric specification for the value added per worker where besides the traditional factors of production, TFP depends on RD, EUINFP and also on the interactions between EUINFP and private capital, and EUINFP and the labour market. We estimate this specification for the 17 Spanish regions for 1989-2010 and find positive marginal contributions for RD, EUINFP and the interdependencies between EUINFP and private capital on the TFP growth rate.

Keywords: *Regional development, Infrastructures, European Regional Development Fund, Cohesion Fund, Spain, Total Factor Productivity*
JEL codes: *R10, R11, R12, R13, R14*

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1. Introduction

The economic path followed by Spain in the 1990s and 2000s lead to an economic growth process mainly characterised by a large investment effort in human capital, business capital and environmental, social and transport infrastructure projects. Despite the important increases in the capital stocks associated to these investments, the intense process of jobs creation of the Spanish economy over the 90s up until the onset of the so called great recession (end of 2007, beginning of 2008) came at the cost of keeping capital and output per worker (labour productivity) stagnated or even with slight decreases (particularly labour productivity) from the mid-nineties until 2007. In sum, during this period Spain featured a growth model based on factor accumulation rather than productivity gains. To put some figures, for instance during the 1995-2007 Spanish expansion prior to the great recession, while GDP grew at 3.5% per year, Total Factor Productivity (TFP henceforth) fell at an annual rate of 0.7%2. Understanding the causes of the low productivity and finding the ways of boosting it is key to overcome the vulnerabilities of the Spanish economy and became one of the priorities of the investments carried out by the European Union (EU) regional and cohesion policy. A very recent research on the sources of this productivity stagnation in Spain was carried out by Garcia-Santana et al. 2016. These authors using a firm-level dataset over the period 1995-2007 from the Central Balance Sheet data (Central de Balances Integrada (CBI) in Spanish) computed different measures of allocative efficiency pointing out that an increase in misallocation of capital and labour across firms within each industry is at the root of this negative TFP growth. Using roughly the same time frame (1995-2008), Escribá and Murgui (2011) analysed the regional and sectoral determinants that explain the heterogeneity of TFP growth across 10 branches of economic activity in the manufacturing and private services sector of the 17 Spanish regions (Comunidades Autonomas). Escribá and Murgui (2011) regress regional TFP levels on a series of explanatory variables that take into account the levels of sectoral specialization, market size, diversification, human capital, infrastructures and technological capital (share of private RD stocks on private capital stock). From their results they emphasize as policy recommendations the need to improve the skills and research and development expenditures (RD) at sectoral level.

[2] This is in sharp contrast to the results on TFP growth over the same period for the United States (+0.6%) and the European Union (+0.4%).

The intense process of capital accumulation experienced by the Spanish economy during the nineties and 2000s took place with the support of the EU regional and cohesion policy. Spain was one of the main recipients of Structural and cohesion funds over this period since many of its regions were under the category of objective 1 regions3 and the allocations of funds were mainly to support agriculture and rural development, business and tourism, investment in education and various measures that improve human capital, investments in infrastructure, transport and environment. However, the increasing number of studies focusing on the estimation of the impact of EU regional policies that appeared after the second half of the 90´s had mixed results. Indeed, some studies do not find significant impact of the funds (Crescenzi, Fratesi, & Monastiriotis, 2017; Dall´erba & Le Gallo, 2008), others find very modest impacts (Rodriguez-Pose & Fratesi, 2004) and some others find positive impacts (Brandsma et al., 2014).

In this context, this paper relates to these two strands of the literature, Spanish TFP dismal performance during the fast factor accumulation decades before the crisis and the impact of EU regional policies on regional and local development, by seeking to answer to which extend RD expenditures and the investments in transport infrastructure supported by the EU regional and cohesion policy contribute to preventing the negative trend of Spanish TFP over this period from falling further. The originality of our approach does not rely on the type of model we use for our purposes. Indeed, we base our theoretical framework on the famous Mankiw, Romer and Weil (1992) growth model. However, unlike previous contributions we incorporate among the TFP drivers of the model the transport infrastructure investment in programs supported with EU and national funds (EUINFP)4. The second originality of our paper consists of incorporating as an additional TFP driver in the growth model the interactions between private investments and cohesion policy investments borrowing the ideas put forward by Redding (1996) in his analysis of the synergies between RD and skills in an endogenous growth model. With this TFP-augmented function we want to test for the existence of potential coordination failures and incentives to invest problem. In other words, we want to test whether the argument that the type of private investment changed (or

[3] NUTS level II areas in the Nomenclature of Territorial Units for Statistics developed by Eurostat with a per capita gross domestic product (GDP) lower than 75 % of the Community average. Objective 1 regions were the recipients of the highest amount of structural and cohesion support.

[4] EUINFP includes national funding from the central and regional governments in transport infrastructure projects

improved) because the presence of the right public investments holds. Finally, the third originality that is incorporated in our TFP function is the effect of transport investments financed with EU and national funds (EUINFP) in the labour market. The idea behind this argument is to check whether the contribution of labour to the production function is enhanced by the EUINFP funded transport investments, i.e. if we can find additional marginal increases in labour productivity due to better matching.

Our results show that despite the productivity stagnation of the Spanish economy during the 1990s and 2000s, the contributions made by the transport infrastructure investments (EUINFP) and the expenditures carried out on Research and Development (RD) have partially prevented the Spanish TFP growth from falling further. Our results also point to the existence of synergies between private investments and transport infrastructure investments (EUINFP). Finally, the results do not support the argument of increases in labour productivity due to synergies between transport infrastructure investments (EUINFP) and the labour market.

The remainder of the paper is organized as follows: section 2 sets out the theoretical growth model and the empirical counterparts that account for the impact of transport infrastructure EU funding and the interdependencies between this funding and private investments as well as interdependencies in the labour market in a Mankiw-Romer-Weil world. Section 3 explains in detail the procedures we follow to compile the ERDF, CF and national funding data in transport infrastructure projects as well as the data and sources on the other variables we use to estimate the empirical specifications. Section 4 presents the results. Finally, section 5 concludes by very briefly framing our analysis and conclusions within the literature of the regional determinants of the economic crisis in Europe and paying special attention to the literature on regional resilience and the regional determinants of the recession (Crecenzi et al., 2017; Cuadrado-Roura, Martin, & Rodriguez-Pose, 2016; Cuadrado-Roura & Maroto, 2016) and outlining some policy implications.

2. A growth model for the Spanish economy

The Model

We start our theoretical discussion by resorting to Mankiw-Romer-Weil (1992) model who augments the Solow model by including accumulation of human as well as physical capital. Additionally, and for the specific reasons related to our research goals-estimating the marginal contributions to the value added per worker of the different production factors- we break down physical capital into business capital and public capital (stock of infrastructures).

Let us denote regions and years by the subindexes i and t, respectively. The starting point in our framework is based on the fact that total output of region i at time t, Y_{it}, is given by an aggregate Cobb-Douglas production function exhibiting constant returns to scale[5] in the reproducible physical and human capital-augmented labour:

$$Y_{it} = A_{it} \cdot H_{it}^{\delta_h} \cdot K_{biz\,it}^{\delta_k} \cdot K_{inf\,it}^{\delta_g} \tag{1}$$

Where Y measures the total production of goods and services, H denotes the human capital-augmented labour used in production, K_{biz} denotes the stock of business aggregate capital, K_{inf} denotes the stock of public infrastructures, and finally, A stands for the aggregate level of technology or the so called total factor productivity (TFP). The coefficients (δ_h, δ_k, δ_g) denote the output elasticities with respect to human capital-augmented labour, business aggregate capital and the stock of transport infrastructures respectively. We assume that the sum of these output elasticities is equal to one, which implies that there are decreasing returns to both types of capital. By assuming that $H = hL$, where h represents the amount of human capital per worker and L represents the amount of labour (which is assumed to be homogenous across the regions of a country), the production function can be rewritten as:

$$Y_{it} = A_{it} \cdot (h_{it} L_{it})^{\delta_h} \cdot K_{biz\,it}^{\delta_k} \cdot K_{inf\,it}^{\delta_g} \tag{2}$$

Letting lower case letters denote variables normalized by the size of the labour force (so that $y_{it} = Y_{it} / L_{it}$ for example), then the production function in intensive form may be written as:

$$y_{it} = A_{it} \cdot h_{it}^{\delta_h} \cdot k_{biz\,it}^{\delta_k} \cdot k_{inf\,it}^{\delta_g} \tag{3}$$

Following Barro and Lee (2010), human capital per worker is assumed to have a relation to the number of years of schooling as follows[6]:

[5] Even though there is a huge amount of research on agglomeration economies and how important are increasing returns to scale to model this phenomenon, for the Spanish economy the assumption of a production function exhibiting constant returns to scale is compatible with estimations based on Spanish data (see for instance Escribá and Murgui (2011)

[6] See also Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999)

$$h_{it} = e^{\varphi\ (s_{it})} \tag{4}$$

Where φs_{it} reflects the efficiency of a unit of labour in region i at year t with s_{it} years of education relative to one with no schooling $\varphi(0) = 0$. Therefore, the derivative $\varphi(s)$ is the return to schooling estimated in a Mincerian wage regression (Mincer, 1974): an additional year of schooling raises a worker´s efficiency proportionally by $\varphi(s)$. Note that if $\varphi(0) = 0$ for all s, Eq. (3) is a standard production function with undifferentiated labour.

We further assume that $\varphi(s_{it})$ is linear,

$$h_{it} = e^{\varphi s_{it}} \tag{5}$$

The final factor in the production of output is the stock of technology, A. We assume that the aggregate level of technology in region i at time t is a function that depends of the following factors:

$$A_{it} = F(\Omega_t, rd_{it-1}, euinfp_{it-1}, K_{biz,\mathrm{it}-1} euinfp_{it-1}, L_{it-1} euinfp_{it-1}) \tag{6}$$

Where all the determinants of the stock of technology are lagged one period to reflect that they normally affect technology in the following period.

Ω_t which represents some amount of technological knowledge identical in all regions and grows at a constant rate λ in all regions. This part of the technological progress is a traditional assumption of the neoclassical growth model.

rd_{it} which represents the yearly regional share of aggregate RD expenditures relative to regional output. Investment in RD has been thought to be one of the major sources of growth in output per worker. The empirical literature often uses RD expenditures to capture the observed growth in productivity (see for instance Escribá & Murgui, 2011; Lopez-Rodriguez & Martinez 2017)

$euinfp_{it}$ which represents the yearly European Union and National Funding in Transport Infrastructure projects (% over transport infrastructure capital stock, K_{infit}). This boosting factor of the technological progress has also been used in the empirical estimations of the main drivers of TFP (see for instance Escribá & Murgui, 2011). The economic rationale behind this factor lies in the fact that the improvement in stock of infrastructures leads to an increase in firms´ productivity

$k_{biz,it} euinfp_{it}$ the theoretical rationale for including this argument in the functional form of the level of technology is based on Redding (1996) who produced a formal model of endogenous growth capturing the interplay between workers who invest in human capital and firms that invest in quality-augmenting RD. Borrowing Redding´s ideas we add the synergies between private investments (changes in business capital stocks) and cohesion policy investments as an additional TFP growth driver so as to corroborate if the argument that the type of private investment changed (or improved) because the presence of the right public investments holds. In other words, with this additional argument in the TFP function we try to proxy the existence of a coordination failure and incentives to invest problem.

$L_{it} \cdot euinfp_{it}$ which proxies the existence of a better matching in the labour market thanks to the EU funded transport infrastructures. We expect a positive contribution of EU funds to the matching between demand for labour and supply of labour.

The factors we have defined in expression (6) are incorporated to our growth model (Eq. 7) by assuming they impinge on the TFP growth rate temporal trend. Therefore, the following functional form for the level of technology in region i at time t is defined:

$$A_{it} = \Omega_t \exp[(\beta_1 rd_{it-1} + \beta_2 euinfp_{it-1} + \beta_3 (K_{biz,\mathrm{it}-1} euinfp_{it-1}) + \beta_4 (L_{it-1} euinfp_{it-1}))\,\mathrm{t}] \quad (7)$$

Where $\Omega_t = \Omega_{0i} \exp(\lambda t)$ with Ω_{0i} denoting initial technology and λ standing for the average cumulative rate of growth of technology and β_1, β_2, β_3 and β_4 representing the boosting effects generated by RD expenditures, transport infrastructure ERDF and CF expenditures, the synergies between private investments and transport infrastructure EU funding and between the labour markets and transport infrastructure EU funding respectively on the average growth rate of TFP.

Substituting expressions (5) and (7) into equation (3) and taking into account the definition of Ω_t, the production function in intensive form may be rewritten as:

$$\begin{aligned} y_{it} &= \Omega_{0i} \exp(\lambda\, \mathrm{t}) \exp[(\beta_1 rd_{it-1} + \beta_2 euinfp_{it-1} + \beta_3 (K_{biz,\mathrm{it}-1} euinfp_{it-1}) + \beta_4 (L_{it-1} euinfp_{it-1}))\,\mathrm{t}] \\ &\cdot \left(\exp(\varphi s_{it})\right)^{\delta_h} (k_{biz,it})^{\delta_k} (k_{\inf,it})^{\delta_g} \end{aligned} \quad (8)$$

Taking logs in Eq. (8) the value added per worker is given by:

$$\begin{aligned} lny_{it} &= ln\Omega_{0i} + \lambda \cdot t + \beta_1 \cdot \mathrm{rd}_{it-1} \cdot t + \beta_2 \cdot euinfp_{it-1} \cdot t + \beta_3 \mathrm{k}_{\mathrm{biz}\,it-1} euinfp_{it-1} \cdot t + \beta_4 L_{it-1} euinfp_{it-1} \cdot t \\ &+ \delta_h \cdot \varphi \mathrm{s}_{it} + \delta_k \cdot \mathrm{lnk}_{\mathrm{biz}\,it} + \delta_g \cdot \ln \mathrm{k}_{\inf it} \end{aligned} \quad (9)$$

Empirical specification

In accordance to Mankiw, Romer and Weil (1992) we argue that the term Ω_{0i} should be interpreted as reflecting not just technology but as reflecting region-specific influences on growth such as resource endowments, climate, and institutions. Hence, we may assume that these differences vary randomly in the sense that:

$$ln\Omega_{0i} = \gamma_i + \varepsilon_{it}$$

Where γ_i is the region-specific component and ε_{it} is the random component of Ω_{0i}. Eq. (9) therefore can be used to justified an error term. Hence the empirical counterpart of the theoretical growth model in Eq. (9) can be expressed as follows:

$$\begin{aligned} lny_{it} &= \gamma_i + \lambda \cdot t + \beta_1 \cdot \mathrm{rd}_{it-1} \cdot t + \beta_2 \cdot euinfp_{it-1} \cdot t + \beta_3 \mathrm{k}_{\mathrm{biz}\,it-1} euinfp_{it-1} \cdot t + \beta_4 L_{it-1} euinfp_{it-1} \cdot t \\ &+ \delta_h \cdot \varphi \mathrm{s}_{it} + \delta_k \cdot \mathrm{lnk}_{\mathrm{biz}\,it} + \delta_g \cdot \ln \mathrm{k}_{\mathrm{inf}\,it} + \varepsilon_{it} \end{aligned} \quad (10)$$

The effects of the stock of regional public infrastructures on value added per worker captured by (K_{inf}) does not properly reflects a region´s needs for transport infrastructures (Crescenzi et al., 2017). These depends on two crucial factors. On the one hand, a good measure of transport infrastructures endowments must consider the real regional need of transport infrastructures endowments on account of its size and population. Densely populated areas as well as very large regions need higher transport infrastructures endowments. To account for this, we weight stocks of regional public infrastructures (K_{inf}) by the geometric mean of both regional population and regional area. On the other hand, this measure must also consider how close a region is to its saturation level were transport infrastructure investments would eventually lose their capabilities to generate further growth and value added per worker increases7. We approach this saturation level by means of a comparing the region´s transport infrastructure stock with a benchmark given by the best endowed region at the end of the period. These two features are taken into account by proposing an alternative measure of capital endowments (k_{infsat}) which mathematically is defined as follows:

$$K_{\mathrm{inf}\,satit} = \frac{\dfrac{K_{\mathrm{inf},it}}{\sqrt{pop_{it} \cdot area_{it}}}}{Max_t\left(\dfrac{K_{\mathrm{inf},it}}{\sqrt{pop_{it} \cdot area_{it}}}\right)} x100 \quad (11)$$

[7] For regions with poor endowments of transport infrastructures, transport infrastructure investments have significant effects in output growth and value added per worker. As regions approach to adequate levels of transport infrastructure endowments, their capabilities to boost growth and value added per worker go through a decreasing path eventually reaching a saturation point.

The index varies in the range (0,100] taking the value 100 for the best-endowed region (the benchmark) and diminishing as we move towards the worst-endowed region.

Substituting in Eq. (10), K_{inf} for this alternative measure of capital endowments (k_{infsat}) given by Eq. (11), yields to our second empirical counterpart:

$$\begin{aligned} lny_{it} &= \gamma_i + \lambda \cdot t + \beta_1 \cdot \text{rd}_{it-1} \cdot t + \beta_2 \cdot euinfp_{it-1} \cdot t + \beta_3 \text{k}_{\text{biz}\, it-1} euinfp_{it-1} \cdot t + \beta_4 L_{it-1} euinfp_{it-1} \cdot t \\ &+ \delta_h \cdot \varphi \text{s}_{it} + \delta_k \cdot \text{lnk}_{\text{biz}\, it} + \delta_g \cdot \ln \text{k}_{\text{inf}\, sat it} + \varepsilon_{it} \end{aligned} \quad (12)$$

Finally, a third measure ($k_{infarea}$) of the infrastructure capital stocks that takes into account the yearly regional endowment per km^2 relative to the yearly total national per square Km has been used[8]. Mathematically, the $k_{infarea}$ can be defined as follows:

$$k_{infareait} = \frac{\dfrac{K_{\text{inf},it}}{Km_i^2}}{\sum_{i=1}^{17} \dfrac{k_{\text{inf,it}}}{Km_i^2}} \quad (13)$$

Substituting in Eq. (10), K_{inf} for this third measure of capital endowments ($k_{infarea}$) given by Eq. (13) and controlling also for the regional level of population yields to our third empirical counterpart:

$$\begin{aligned} lny_{it} &= \gamma_i + \lambda \cdot t + \beta_1 \cdot \text{rd}_{it-1} \cdot t + \beta_2 \cdot euinfp_{it-1} \cdot t + \beta_3 \text{k}_{\text{biz}\, it-1} euinfp_{it-1} \cdot t + \beta_4 L_{it-1} euinfp_{it-1} \cdot t \\ &+ \delta_h \cdot \varphi \text{s}_{it} + \delta_k \cdot lnk_{biz\, it} + \delta_g \cdot lnk_{infareait} + pop_{it} + \varepsilon_{it} \end{aligned} \quad (14)$$

All equations have been estimated by OLS using the fixed effects (FE) estimator (within estimator) to control for regional unobserved heterogeneity and to allow for arbitrary correlation between the regional fixed effects and the explanatory variables.

3. Data

This paper combines several sources of information to gather the data we need to carry out our estimations. Mainly four data sources, the Valencian Institute of Economic Research, (IVIE), the Spanish National Statistics Institute, (INE), The Spanish ministry of Education, Culture and Sports (MECS) and the former Spanish Ministry of Economics and Finance (MEF), have been used for the data regarding the main macroeconomic variables of the model (Value added per worker, human capital

[8] We thank a referee for suggesting us the estimation of this third alternative.

augmented-labour, business capital, infrastructure capital and research and development expenditures).

Data on the variable that proxies the transport infrastructures EU funding (euinfp) has been obtained from the European regional policy annual reports issued from 1989 until 2010 by the Directorate General of Community funds of the Spanish ministry of Economics and Public Finance (Known in the Spanish jargon as DG Fondos). Within the time frame of our empirical exercise we analysed the information contained in the annual reports issued over the four programming periods since the Spanish adhesion to the EU, (1989-1993), (1994-1999), (2000-2006) and (2007-2013) on the amounts invested by region and year in transport infrastructures financed by the ERDF and Cohesion Fund, as well as central and regional governments funding (see more details in the data appendix). Table 1 describes variables, definitions and data source:

Table 1: Variables definition and sources

Variable	Definition	Source
lny_{it}	Log of Value added per worker of region i in year t between 1989 and 2010	IVIE
φs_{it}	Efficiency of a unit of labour in region i at year t with sit years of education relative to one with no schooling t between 1989 and 2010 (see computation details in the data appendix)	IVIE and MECS
$lnk_{biz\,it}$	Log of private capital (non-housing business capital) in region i at year t between 1989 and 2010	IVIE
$lnk_{inf\,it}$	Log of infrastructures capital in region i at year t between 1989 and 2010	IVIE
$lnk_{infsat\,it}$	Log of k_{infsat} in region i at year t between 1989 and 2010 $$K_{infsat\,it}=\frac{\frac{K_{\inf,it}}{\sqrt{pop_{it}\cdot area_{it}}}}{Max_t\left(\frac{K_{\inf,it}}{\sqrt{pop_{it}\cdot area_{it}}}\right)}x100$$	Own elaboration based on IVIE
$lnk_{infarea\,it}$	Log of $k_{infarea}$ in region i at year t between 1989 and 2010 $$k_{infarea\,it}=\frac{\frac{K_{\inf,it}}{Km_i^2}}{\sum_{i=1}^{17}\frac{k_{\inf,it}}{Km_i^2}}$$	Own elaboration based on IVIE
rd_{it-1}	Research and development expenditures of region i in year t as percentage of gross domestic product (at constant 2000-euro) between 1989 and 2010, constant 2000-euro	INE
$euinfp_{it-1}$	ERDF, CF and national funding regional investments in transport infrastructures relative to regional transport infrastructures capital stocks ($k_{inf\,it-1}$) of region i in year t between 1989 and 2010 (%)	MEF and IVIE
L_{it-1}	Employed people of region i in year t between 1989 and 2010	INE
pop_{it}	Population of region i in year t between 1989 and 2010	INE
$k_{biz\,it-1}euinfp_{it-1}$	Interaction term to test the interdependencies (synergies) between business capital and euinfp	MEF, IVIE and INE
$L_{it-1}euinfp_{it-1}$	Interaction term to test the interdependencies (synergies) between employment and transport infrastructure (euinfp)	MEF, IVIE and INE

Note: 1) The variables log of value added per worker, log of private capital, log of infrastructures, research and development expenditures and European funds' investments in transport infrastructures are measured at constant 2000 euro. 2) IVIE (The Valencian Institute of Economic Research), INE (Spanish National Statistics Institute), MEF (Spanish Ministry of Economics and Finance), MECS (Spanish Ministry of Education, Culture and Sports)

4. Results

We start this section by first presenting the descriptive statistics of the variables, their pair-wise correlations, the aggregate data on transport infrastructures EU funding jointly with several graphs that offer a visual inspection of the variables that are important in explaining the growth process followed by the Spanish economy. Them, we continue with the results of the estimations.

Table 2 shows the descriptive statistics of the variables and their pair-wise correlations. The database we build is a strong balanced panel with 372 observations which correspond to the 17 Spanish regions observed over the period 1989-2010.

Table 2: Summary statistics and pair-wise correlation among variables

Variables	Obs	Mean	Std. D.	Min	Max
y_{it} (value added per worker)	372	39294.1	5524.98	25218.1	51827.2
rd_{it} (Research and development expenditures -%)	372	0.78042	0.46894	0.09000	2.41000
$euinfp_{it}$ (ERDF, CF and national funding invests in regional transport inf. -% k_{infit})	372	0.02615	0.02264	0.00000	0.11248
φs_{it} (Efficiency of a unit of labour)	372	1.05701	0.07708	0.82494	1.22577
k_{bizit} (Business capital per worker)	372	54501.8	9807.98	26148.6	84418.4
k_{infit} (Capital stock in transport infrastructure per worker)	372	8068.87	3248.46	2220.36	17036.8
$k_{infsatit}$ (Inf. endowment weighted by population and area relative to the best- endowed region)	372	33.6462	16.9396	7.54389	100.000
$k_{infareait}$ (Inf. endowment per km2 relative to the yearly total national per square Km)	372	0.05880	0.05556	0.00975	0.26913

Pair-wise correlations	lny_{it}	rd_{it}	$euinfp_{it-1}$	φs_{it}	lnk_{bizit}	$lnk_{inf\,it}$	$lnk_{infsatit}$	$lnk_{infareait}$
lny_{it}	1.0000							
rd_{it}	0.3914	1.0000						
$euinfp_{it-1}$	-0.2832	0.1676	1.0000					
φs_{it}	0.4966	0.8038	0.2968	1.0000				
lnk_{bizit}	0.5417	0.5701	0.1230	0.6159	1.0000			
$lnk_{inf\,it}$	0.0123	0.2027	0.1667	0.0983	0.4277	1.0000		
$lnk_{infsatit}$	0.5543	0.6688	0.1470	0.7248	0.5006	0.3446	1.0000	
$lnk_{infareait}$	0.5594	0.2881	-0.1266	0.3551	0.0896	-0.2363	0.7327	1.0000

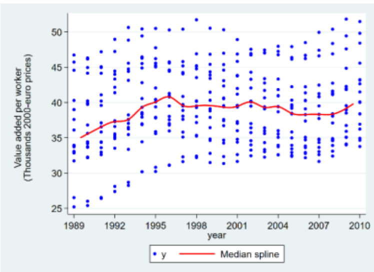
Source: Own elaboration

It can be observed that all the pair-wise correlations have the expected signs. It is worth highlighting the negative correlation between value added per worker and European investments in transport infrastructures since EU funds are mainly channelled to backward regions.

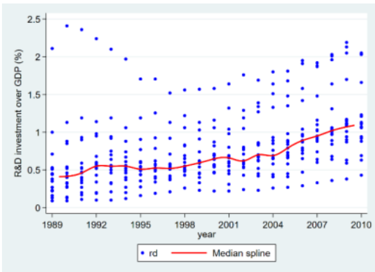
Figure 1 provides a visual image of the main features of the pattern of growth process followed by the Spanish economy over the period 1989-2010. In the upper part of Figure 1 we plot the evolution of value added per worker (y_{it}), the patterns followed by the expenditures on research and development relative to GDP (rd_{it}) and the evolution of the efficiency of labour due to human capital investments (φs_{it}). With regard to y_{it} we observe that after a first period (1989-1996) of important increases, the following years up to the irruption of the so called great recession are characterized by a mild declining and from 2008 onwards value added per worker gains momentum mainly due to the sharp adjustments in the labour market caused by the great recession (the unemployment rate began an uninterrupted increase that by the start of 2014 reached 25.7% of the active population). With regard RD expenditures they were very low until the late 90s (around 0.5%). Nonetheless they started to grow from the late 90s onwards reaching a value slightly above 1% in 2009. The upper-right part of Figure 1 plots the evolution of (φs_{it}). It can be seen the important increases experienced by the efficiency of labour until 2006-2007 which were followed by a stagnant path after the irruption of the great recession that might be attributed to the sharp fall of new graduates getting a job and the migration of highly skilled people to other countries. The bottom-left part of Figure 1 plots the evolution of the per worker business capital stocks (k_{bizit}) – that show important increases up to 1995, stagnation from 1996-2007 and again important increases after the onset of the great recession.

Figure 1: Value added per worker, RD expenditure over GDP, Efficiency of labour due to Human Capital and Business capital per worker and Transport Infrastructure Capital Stocks (Spain, 1989-2010, Thousand € at constant 2000 prices).

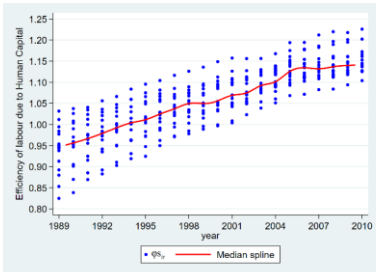
Value added per worker (y_{it})



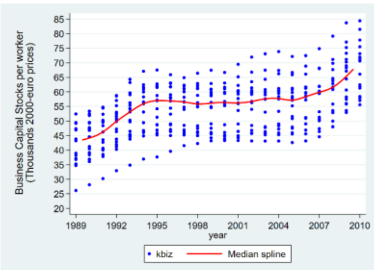
RD expenditure over GDP (rd_{it} , %)



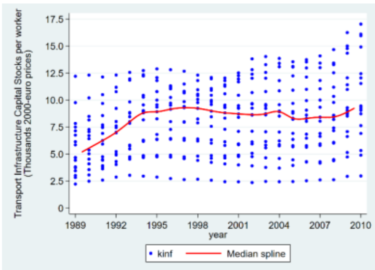
Efficiency of labour due to Human Capital (φs_{it})



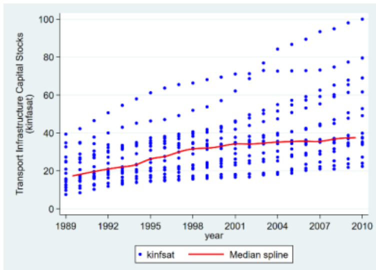
Business Capital Stocks per worker (k_{bizit})



Transport Infrastructure Capital Stocks (k_{infit})



Transport Infrastructure Capital Stocks ($k_{infsatit}$)



Source: Own elaboration from our database

The bottom-middle part of Figure 1 provides the pattern followed by the per worker transport infrastructure capital stocks (k_{infit}). The graph shows a mild decrease because of the large transport infrastructure investments boosted by EU funding up to 2003-2004 (see Figure 1A in the data appendix) were compensated by even faster increases in employment (capital widening process). Finally, the bottom-right part of Figure 1 plots $k_{infsatit}$ which is intended to capture the true needs a region might have on account of the large differences in size and population density of the Spanish regions as well as how close a region is to the benchmark of transport infrastructure saturation level[9].

Tables 3, 4 and 5 summarize the estimation results of specifications given by Eq. 10, 12 and 14 applying the fixed-effects estimation technique. Several indications can be extracted from columns 1 to 7 (8-13, and 14-19) of Table 3 (4 and 5). First of all, the variables with the greatest influence on the level of productivity per worker over the period of analysis are the investments in human capital with elasticity estimates in the range 0.393-0.638 (0.465-0.622 and 0.331-0.498) and per worker business capital stocks with elasticity estimates in the range 0.241-0.547 (0.508-0.547 and 0.474-0.547). The estimated elasticities for the transport infrastructures capital stocks on productivity per worker are much lower. They are in the range 0.124-0.166 (Columns 1-6) for k_{infit} and (0.0383-0.071 and 0.0145-0.0669) for $k_{infsatit}$ and $k_{infareait}$ respectively. The signs of the estimated coefficients for these variables, with the exception of the coefficient estimates for the alternative measures of transport infrastructures capital stocks $k_{infareait}$ in column 15 (Table 5), are in line with the theoretical expectations (positive) and they are statistically significant at the standard significant levels. When we additionally control for the interaction between k_{infit} and the distance to the benchmark given by Eq. 11 (1-$k_{infsatit}$) (Column 7) the coefficient estimate is positive and statistically (0.0702). It shows that the larger the gap to the benchmark the higher the impact on productivity.

[9] Following a suggestion made by a referee we have also defined another alternative metric for transport infrastructures capital stocks, $k_{infarea_{it}}$. See data appendix

Table 3: Regression Results for Log Output per Worker (Eq. 10)

	1	2	3	4	5	6	7
t	-0.0112***	-0.00967***	-0.0149***	-0.0153***	-0.0158***	-0.0157***	-0.0148***
	(0.0017)	(0.0016)	(0.0019)	(0.0019)	(0.0019)	(0.0019)	(0.0018)
φs_{it}	0. 498**	0.393**	0.623***	0.579***	0.638***	0.634***	0.536***
	(0.1480)	(0.1403)	(0.1435)	(0.1453)	(0.1476)	(0.1485)	(0.1380)
lnk_{bizit}	0.547***	0.385***	0.312***	0.328***	0.318***	0.314***	0.241***
	(0.0328)	(0.0392)	(0.0416)	(0.0424)	(0.0425)	(0.0455)	(0.0433)
lnk_{infit}		0.124***	0.166***	0.157***	0.156***	0.156***	0.149***
		(0.0184)	(0.0194)	(0.0199)	(0.0198)	(0.0201)	(0.0187)
rd_{it-1}			0.00294***	0.00318***	0.00317***	0.00318***	0.00522***
			(0.0006)	(0.0006)	(0.0006)	(0.0006)	(0.0006)
$euinfp_{it-1}$				0.0168	-0.0851	-0.0552	-0.0717
				(0.0095)	(0.0516)	(0.1157)	(0.1071)
$k_{biz}euinfp_{it-1}$					0.00000176*	0.00000171	0.00000161
					(8.77e-07)	(8.97e-07)	(8.29e-07)
$Leuinfp_{it-1}$						-0.0310	-0.0103
						(0.1075)	(0.0996)
$lnk_{inf}(1-k_{infsat})_{it}$							0.0702***
							(0.0101)
Observations	372	372	355	355	355	355	355
Estimation method	FE	FE	FE	FE	FE	FE	FE
Annual average contribution to TFP growth:							
rd			0.00223	0.00249	0.00248	0.00249	0.00408
Within R-squared	0.4929	0.5509	0.5647	0.5687	0.5739	0.5740	0.6383
F-Statistic	114.05	107.64	86.40	72.97	63.70	55.59	64.32
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Table shows standard errors between brackets (* $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$)

Table 4. Regression Results for Log Output per Worker (Eq. 12)

	8	9	10	11	12	13
t	-0.0112***	-0.0121***	-0.0170***	-0.0173***	-0.0179***	-0.0180***
	(0.0017)	(0.0017)	(0.0222)	(0.0022)	(0.0022)	(0.0022)
φs_{it}	0.498***	0.465**	0.618***	0.542***	0.617***	0.622***
	(0.1480)	(0.1486)	(0.1562)	(0.1569)	(0.1592)	(0.1602)
lnk_{bizit}	0.547***	0.530***	0.508***	0.523***	0.506***	0.510***
	(0.5466)	(0.0340)	(0.3622)	(0.0362)	(0.0367)	(0.0400)
$lnk_{infsatit}$		0.0383*	0.0711**	0.0571*	0.0595*	0.0579*
		(0.0213)	(0.0229)	(0.0232)	(0.0230)	(0.0239)
rd_{it-1}			0.00215**	0.00257***	0.00258***	0.00257***
			(0.0007)	(0.0007)	(0.0007)	(0.0007)
$euinfp_{it-1}$				0.0288**	-0.0988	-0.128
				(0.1029)	(0.5589)	(0.1258)
$k_{biz}euinfp_{it-1}$					0.00000220*	0.00000224*
					(9.46e-07)	(9.64e-07)
$Leuinfp_{it-1}$						0.0309
						(0.1183)
Observations	372	372	355	355	355	355
Estimation method	FE	FE	FE	FE	FE	FE
Annual average contribution to TFP growth:						
rd			0.00168	0.00201	0.00203	0.00201
euinfp				0.00075		
kbizeuinfp (t-1)					0.00305	
Within R-squared	0.4929	0.4975	0.4846	0.4965	0.5046	0.5047
F-Statistic	114.05	86.89	62.62	54.56	48.15	42.03
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Table shows standard errors between brackets (* $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$)

Table 5. Regression Results for Log Output per Worker (Eq. 14)

	14	15	16	17	18	19
t	-0.0112***	-0.00540**	-0.0102***	-0.0111***	-0.0113***	-0.0109***
	(0.0168)	(0.0016)	(0.0018)	(0.0018)	(0.0018)	(0.0019)
φs_{it}	0.498***	0.227	0.421**	0.331*	0.352*	0.340*
	(0.1480)	(0.1359)	(0.1370)	(0.1366)	(0.1401)	(0.1412)
lnk_{bizit}	0.547***	0.513***	0.474***	0.487***	0.484***	0.474***
	(0.0328)	(0.0300)	(0.0313)	(0.0391)	(0.0313)	(0.0341)
$lnk_{infareait}$		0.0145	0.0669**	0.0530*	0.0521*	0.0562*
		(0.0208)	(0.0219)	(0.0218)	(0.0218)	(0.0225)
pop_{it}		-0.000110***	-0.000132***	-0.000130***	-0.000128***	-0.000130***
		(1.19e-05)	(1.19e-05)	(1.17e-05)	(1.19e-05)	(1.22e-05)
rd_{it-1}			0.00356***	0.00405***	0.00402***	0.00408***
			(0.0006)	(0.0006)	(0.0006)	(0.0006)
$euinfp_{it-1}$				0.0327***	-0.0000831	0.0739
				(0.0088)	(0.4893)	(0.1116)
$k_{biz}euinfp_{it-1}$					0.000000566	0.000000424
					(8.31e-07)	(8.54e-07)
$Leuinfp_{it-1}$						-0.0759
						(0.1029)
Observations	372	372	355	355	355	355
Estimation method	FE	FE	FE	FE	FE	FE
Annual average contribution to TFP growth:						
rd			0.00278	0.00316	0.00315	0.00320
euinfp				0.00085		
Within R-squared	0.4929	0.5964	0.6127	0.6283	0.6288	0.6294
F-Statistic	114.05	103.43	87.53	79.93	69.88	62.09
Prob > F	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

Note: Table shows standard errors between brackets (* $p < 0.1$, ** $p < 0.01$, *** $p < 0.001$)

Second, the coefficient of the temporal trend (t) which proxies the average TFP growth rate in the period is negative and statistical significant in all the estimations. This result is in line with Mas and Quesada (2006), Escribá and Murgui (2011) and Garcia-Santana, Moral-Benito, Pijoan-Mas and Ramos (2016) findings for the Spanish economy. Third, the marginal estimated impacts on the growth rate of TFP of the expenditures in research and development (rd) are positive in all the estimations and statistically significant at the usual significance levels. When we additionally control for the contribution of ERDF, CF and national funding investments in transport infrastructures ($euinfp$) -columns 4-7 (11-13 and 17-19) the estimated marginal boosting effects of rd and $euinfp$ on the TFP growth rates are both positive and statistically significant only for Eq. 12 and 14 (Columns 11 and 17). The implied contributions10 of rd and euf to the annual TFP growth rate are in the range of 0.2% and 0.32% (rd) and 0.075% - 0.085% ($euinfp$). The main reason for the positive contribution of $euinfp$ to TFP growth comes from the idiosyncratic features of the Spanish economy in the period. Most Spanish regions were lagging behind at the

[10] This value is computed by multiplying the estimated coefficient of "rd" by the average value for this variable.

beginning of our period of analysis with major gaps in transport infrastructures which were largely narrowed down during the 90s and 2000s thanks to the important aid from ERDF and CF investments. It is worth remarking that the expenditures in research and development (rd) have a greater boosting effect on TFP growth than the investments associated to ERDF, CF and national funding ($euinfp$). Net of these positive contributions, the growth rate of TFP in the period is negative with an average cumulative rate (λ) between -0.71%, -0.78%. These results are similar to those obtained by Garcia-Santana et al. (2016) and signal the process of decreasing labour productivity followed by the Spanish economy in most of the years of our time frame as was highlighted in Figure 1.

Fourth, we include in our estimations additional boosting drivers on the TFP growth rates to control for the existence of a coordination failure and incentives to invest problem ($k_{bizit} euinfp_{it}$) columns 5-7 of Eq. 10 and (11-13 and 18-19) of Eq. 12 and Eq. 14. The estimated impact of this interaction term is positive in all estimations and statistically significant in Eq. 10 column 5 and Eq. 12 columns 12 and 13 with and implied contribution to TFG growth of 0.3%. Controlling for this interaction term the $euinfp$ coefficient becomes not significantly different from zero, since its effect is captured and reinforced in the interaction (0.07% versus 0.3%). These results point to the fact that regional private investments might improve if the regions count with the right amounts of public ones. It is important to highlight that transport infrastructure EU funding enhances the credibility of programmed transport infrastructure investments due to two important factors: a) EU funding alleviates the usual budget constraints linked to huge investments associated to transport infrastructures; b) EU funding is framed within a binding agreement between the EU commission and the governments (Community support frameworks -CSF- and the corresponding operational programs- Ops-) which significantly reduces the uncertainties about the right implementation of these projects. This positive effect of the interaction captures the positive private investors´ reactions to a credible commitment about reaching the right amounts of transport infrastructure endowments. To some extend the mechanism behind our results resembles the one put forward by Redding (1996) in his multiple growth equilibria model which features that an economy can be trapped in a low-skills equilibrium because of a coordination failure between investments in human capital and RD. Despite the similarities in the coordination failure mechanism, transport infrastructures, unlike RD, are not endogenous growth drivers and therefore their growth boosting effect is fading away as transport infrastructures endowments approach to the neighbourhood of saturation levels, i.e. this positive interaction works as long as regions are suffering from sizeable gaps in transport infrastructures and they are far enough from reaching adequate levels.

Despite achieving high growth per capita rates, the Spanish economy was unable to solve the coordination failure implied in the RD-Skills interaction and remained trapped in the low-productivity-low skills equilibrium (Redding, 1996). The recent literature on resilience (Crescenzi et al. 2016; Cuadrado-Roura et al. 2016; Cuadrado-Roura & Maroto, 2016) highlights the crucial role of productivity as one of the main driving factors of regional resilience. For the Spanish case, Cuadrado-Roura & Maroto, 2016, show that the most resilient regions (those which adjusted productivity with less severe employment adjustments) feature a productive specialization in higher value-added industries as well as better productivity records before and after the onset of the crisis. Crescenzi et al., 2016, in their analysis for the EU15, find out that the resilience at the regional level is not only based on "technology-driven innovation (formal RD investments) but rather a generally innovation-prone environment (abundance of human capital)". In the Spanish case (with already high human capital endowments) additional factors must be considered. A creative class à la Florida (2005) and a better matching both in the innovation system (Redding, 1996) and in the labour market (Rodriguez-Pose and Vilalta-Bufi, 2005) to boost entrepreneurial and business models innovation to generate activities of higher value added per worker will be necessary conditions to strengthen the position of the Spanish regions.

Fifth, we include a last boosting driver on the TFP function to control for a potential better matching in the labour market due to the presence of the right public funding ($L_{it}euinfp_{it}$) in columns 6-7 of Eq. 10 and 13 and 19 of Eq. 12 and Eq. 14. The results of the estimations show non-significant impacts. One potential explanation for these results is that the variables that better capture the matching in the labour market are variables like training given by the employers, Job related training, as well as motivation factors which induce work engagement (Rodriguez-Pose & Vilalta-Bufi, 2005). These variables are not related to EU funding of transport infrastructure.

Our preferred estimates correspond to Eq. 12-colums 11-13), since a) the measure we have defined to control for the transport infrastructure capital stocks k_{infsat} better reflects the regional needs for improving their transport infrastructure endowments, b) The elasticities of the main production factors (human capital, business capital and transport infrastructures capital) fit better with the empirical literature on growth and the empirical evidence obtained for Spain (Escribá & Murgui, 2011). Moreover, the results related to the effect of transport infrastructures capital on the levels of regional development in Spain are also in line with previous specific empirical studies on the subject (Alvarez-Ayuso & Blazquez, 2014, Alvarez-Ayuso & Delgado-Rodriguez, 2012).

In sum, the models we have estimated provide evidence on the boosting effects of both the transport infrastructure investments financed with EU and national funding and the expenditures in research and development on the TFP growth rates and also on the synergies between business capital and transport infrastructure capital. The channel through which this synergy operates is by solving a "coordination failure" resembling the one put forward by Redding (1996) for the interaction between RD and skills but lacking its endogeneity nature and cumulative effects (the boosting effects of transport infrastructures are vanishing as regions approach to an adequate endowment level). A region may become trapped in a "poor-transport infrastructures" equilibrium because of the coordination failure that often occurs when the public investment plans by governments, especially in transport infrastructures, are not able enough to raise credible business expectations for enhancing private investors´ engagement.

Finally, despite the net positive contributions of these productivity drivers they were not able to offset the overall negative downward trend of TFP and the stagnant levels of value added per worker.

5. Conclusions and policy implications

This paper has analysed the role played by transport infrastructure investments in projects financed with EU and national funding in preventing Spanish TFP from falling farther. We have based our analysis in the estimation of a Mankiw-Romer-Weil (1992) growth model augmented with a TFP function which depends on research and development, transport infrastructure investments financed with EU and national funding and controlling for the interdependencies between EU funding and national funding and both private business capital and a better matching between the demand for labour and supply of labour. Our results provide evidence on the positive role played by transport infrastructure investments financed with ERDF, CF and national funding in partially offsetting (positive marginal contributions) the negative trend followed by TFP in Spain over the 1989-2010 period. The channel through which these investments positively impact TFP growth is by solving a coordination failure which would prevent on the one hand private investors´ to take the right decisions to reach an optimal capital allocation and on the other to set in motion a process reinforcing the productivity levels of the economy. Although this mechanism is effective to improve the productivity levels of the Spanish economy when a poor transport infrastructures endowment acts as a binding growth bottleneck, its impact is not as large and long-lasting as the one associate to the effect of RD.

Even though private business capital investments accompanied and fuelled the high growth rates of both per capita GDP and employment levels, the Spanish growth model was mainly based on a strong process of jobs creation by absorbing the large number of structural unemployment11 along with a capital widening. The Spanish economy was unable to improve the resource allocations towards activities generating higher value added per worker. The main reason for this resides in the difficulties to solve the coordination failure when the economy is trapped in a "low-skills-low RD" equilibrium. Our results support the important boosting effects of RD on TFP growth however they were not enough to offset the negative TFP growth trend on account of the low investments in RD and in particular the strong imbalance between business and public RD expenditures. The business efforts in RD were very limited and the business sector was not able to undertake a path towards a better reallocation of its resources preventing the economy to increase value added per worker and to keep it with a dismal TFP performance. Our results are in line with the recent literature on resilience (Cuadrado-Roura & Maroto, 2016, Crescenzi et al., 2016) which emphasizes the crucial role played by productivity and innovative business environments to face the challenges posed by economic downturns.

The prescription of this paper from the point of view of future EU regional policy design is to focus on overcoming the coordination failures envisage in Redding (1996) multiple growth equilibria model that hamper regional transitions to a high skills-high productivity growth equilibrium. This policy design implies a place-based oriented policy boosting the entrepreneurial discovery process which is at the core of the regional innovation smart specialization strategies. To this regard, and particularly for Spanish regions, it is crucial to reinforce the EU regional policies to have a better

[11] The average unemployment rate for the period 1980-1987 was 17.8%

matching between innovative business ideas, new types of activities and the skills and managerial capacities demanded for them.

Interesting further research avenues along the lines of the research carried out in this paper will be to control for potential problems of spatial autocorrelation by means of spatial econometric techniques and also dealing with endogeneity problems. The extension of this analysis to the EU regions or to a much larger sample set that the one used in this paper would allow on the one hand to handle the later problem in an accurate way and on the other to have a more in-depth knowledge on the effects of transport infrastructures investments financed with EU and national funds on productivity levels, not only transport infrastructures but also along the other objective/axis of EU regional policy.

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