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This is an **author produced version** of a paper published in:

Applied Economics 48.24 (2016): 2238-2252

DOI: <https://doi.org/10.1080/00036846.2015.1117048>

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The Public Sector and Convergence with Spatial Interdependence: Empirical Evidence from Spain*

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November 2015

Abstract

We propose a framework to analyse convergence between regions, incorporating the public sector and technological knowledge spillovers in the context of a Neoclassical Growth Model. Secondly, we apply novel estimation methods pertaining to the spatial econometrics literature introducing a spatial Durbin panel data model based on instrumental variables and Maximum Likelihood estimation. Our model makes it possible to analyse, in terms of convergence, the results obtained in Spanish regions with the policies implemented during the period 1980–2011. The results support the idea that education and fiscal policies have a positive effect on regional development and cohesion. Therefore, we can conclude that it is possible to obtain better results for regional convergence with higher rates of public investment in education and tax revenues. We also obtain interesting results that confirm the existence of spillover effects in economic growth and public policies, identifying their magnitude and significance.

Keywords: speed of convergence; growth model, public policy.
JEL Codes: E13; O41; H54

* We are grateful to the editor, two anonymous referees, David N. Weil, J.L. Zofío, and participants at the 60th NARSC Meeting, the 53rd ERSa Congress, and the 6th Seminar Jean Paelinck for their helpful comments and suggestions. Authors acknowledge financial support from the Spanish Ministry of Science and Innovation (ECO2010-21643). Javier Barbero acknowledges financial support from the Spanish Ministry of Education (AP2010-1401).

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1. Introduction

The main goal of this paper is to analyse the impact of the public sector on economic growth and cohesion. With this aim in mind, we evaluate the effect of public policies on cohesion based on a generalized version of the Neoclassical Growth Model proposed by Mankiw et al. (1992) and, following Ertur and Koch (2007) and Fischer (2011), including spatial interactions. The literature on economic growth has devoted considerable effort to the analysis of the determinants of economic growth and the speed of convergence. An extensive and influential number of research papers demonstrate the existence of conditional convergence; that is, the tendency of the most backward economies to systematically grow at a faster rate than more developed economies, once the conditioning factors of this process are controlled for (Mankiw et al., 1992; Barro and Sala-i-Martin, 2004). In a recent paper, Chapsa and Katrakilidis (2014) analysed the income convergence in European countries from 1950 to 2010, highlighting that the results showed the existence of two clubs.

In the context of the European Union, and specifically in the case of Spanish regions, development and cohesion policies have received a great deal of attention due to the fact that, according to the European Commission, they have contributed positively to regional growth and convergence.¹ However, public investment policies oriented to intensify infrastructure equipment and education have often been questioned arguing that they mainly serve distributional purposes, but have little effect on fostering economic growth and convergence.² In this sense, Salinas-Jimenez et al. (2006) highlighted the fact that policies aimed at promoting Total Factor Productivity (TFP) growth should be reinforced, while in a recent paper Bauer et al. (2012) have remarked on the importance of technology using an augmented growth model that includes tax burdens and public investment in a panel of the 48 contiguous states of the United States (US).

Numerous papers in this literature show that the speed of convergence varies across studies, depending on the specification and controlling for investment rates in physical and human capital.³ Some other studies have tried to consider this issue but using different alternative measures. This is the case of Dowrick et al. (2003), Becker et al. (2005) and Philipson and Soares

¹ See the different Cohesion Reports of the European Commission (1997, 2001, 2004, and 2007). For a good survey of the models used to evaluate the macroeconomic impact of EU cohesion policies, see Ederveen et al. (2003).

² For a critique on structural policies in Europe see, for example, Boldrin and Canova (2001).

³ See De la Fuente (2002) for an extended revision of the literature

(2001), among others. Dowrick et al. (2003) proposed their own index based on consumption and life expectancy, Becker et al. (2005) analysed welfare inequality, while Philipson and Soares (2001) examined the properties associated to income.

Most recently, Pastor and Serrano (2012) focused on the inequality in permanent income in the context of European integration, using an approach complementary to Serrano (2006) and Pastor and Serrano (2008). At the same time, and following the convergence studies based on current per capita income, other research works enriched this approach with a methodology that also includes spatial interactions in an extended neoclassical model as determinant of convergence (Ertur and Koch, 2007). LeGallo et al. (2003) and LeGallo and Dall'erba (2006, 2008) introduce spatial interactions in convergence between European regions performing empirical contrasts based on spatial econometric techniques. In the case of Spanish provinces, Tortosa-Ausina et al. (2005) analyse the evolution of disparities including spatial spillovers, obtaining a marked convergence process when the geographic location is taken into account. Recently, Pfaffermayr (2012) highlighted the importance of knowledge spillovers in the speed of convergence in European regions. To our knowledge, the Ertur and Koch (2007) approach has been used in two recent papers, Fischer (2011) and Dall'erba and Llamosas-Rosas (2014). Therefore, the standard model used in the literature does not take into account the public sector and fiscal policies as determinants of economic growth and regional cohesion. This study distinguishes itself from all previous contributions by offering a spatial panel approach, an estimation of the effect of taxes, which provides a more balanced view of the role of government intervention in the economy and estimation of the Spanish regions.

This paper seeks to make a contribution to this debate by offering a useful proposal to evaluate how the convergence process might have resulted under alternative public policies which differ in the rate of public investment. Particularly, in this study we pay attention to the effect on the speed of convergence of an increase in the rate of investment in public and in human capital endowments, since development and cohesion policies incorporate spatial interactions through knowledge spillovers in the production process.

It is worth noting that in this study we deliver this contribution in three distinctive ways. Firstly, we incorporate public sector and fiscal policies in the Mankiw et al. (1992) extended neoclassical growth model with human capital, along with knowledge spillover, in line with the recent literature that introduces spatial interactions to analyse the determinants of convergence.

Secondly, following Álvarez et al. (2013), we implement programming routines in MATLAB⁴ that allow us to apply novel estimation methods pertaining to the spatial econometrics literature (Kelejian and Prucha, 1998, 2010; Baltagi and Liu, 2011).⁵ Thirdly, using a novel dataset, an empirical contrast is performed with Spanish regions during 1980-2011, a critical period in Spanish economic growth after joining the European Union (EU) in 1986. Particularly, the weight matrix reflects proximity between NUTS 3 (Nomenclature of Territorial Units for Statistics) provinces based on contiguity.

Building on the proposed framework, the estimated convergence equation is based on spatial econometric techniques developing a proposal in which estimations are repeated with different public policies. Different scenarios are derived that make it possible to estimate the speed of convergence in Spanish regions resulting from increases in each determinant by dividing the sample by income level per worker. These analyses allow us to provide some public policy recommendations in order to improve economic convergence and regional cohesion.

This paper is organized as follows. Section 2 outlines the derivation of the growth model employed. Section 3 presents the data and results. The final section draws the main conclusions.

2. The Model

2.1 The production function with knowledge spillovers

The economy is characterized by a Cobb-Douglas production function for N regions along T periods with constant returns to scale:

$$Y_{it} = A_{it} K_{it}^{\alpha_K} P_{it}^{\alpha_P} H_{it}^{\alpha_H} L_{it}^{1-\alpha_K-\alpha_P-\alpha_H} \quad (1)$$

where Y_{it} is the production of the i -th region in period t , K_{it} and P_{it} are the physical private and public capital, respectively, H_{it} represents human capital, and L_{it} is the employment level. The parameter A_{it} captures the level of technological knowledge. The production function is well-behaved, satisfying the desirable neoclassical properties or regularity conditions: i) the marginal productivities are positive and decreasing; ii) it meets the Inada conditions; and iii) it shows

⁴ These routines are available on <http://www.paneldatatoolbox.com>.

⁵ Arbia et al. (2008) analyse the convergence in European regions on the basis of the neoclassical Solow model. They consider variations on the basic specification of the convergence equation ranging from standard panel data models to Bayesian models. The results obtained from different estimation strategies concluded that the evidence on regional convergence depends to a large extent on the econometric techniques.

decreasing scale performance in the cumulative factors. We assume α_K , α_P and $\alpha_H > 0$, allowing us to analyse the behaviour of this economy in the steady state, as well as to empirically solve the corresponding convergence equation.

Equation (1) can be rewritten in per worker terms by dividing both sides by the employment L_{it} :

$$y_{it} = A_{it} k_{it}^{\alpha_K} p_{it}^{\alpha_P} h_{it}^{\alpha_H} \quad (2)$$

where y_{it} , k_{it} , p_{it} and h_{it} are production, physical private and public capital, and human capital per worker respectively.

We define technological knowledge as:⁶

$$A_{it} = \Omega k_{it}^{\theta} p_{it}^{\phi} h_{it}^{\gamma} \prod_{j=1}^N k_{jt}^{\theta \rho w_{ij}} p_{jt}^{\phi \rho w_{ij}} h_{jt}^{\gamma \rho w_{ij}} \quad (3)$$

It is worth noting several aspects of modelling the aggregate level of technology proposed as in (3), in accordance with the specification introduced by Fischer (2011). Technology is expressed as a function of a term Ω , reflecting the exogenous common knowledge, physical and human capital of the own region and neighbour regions. The technological parameters $0 < \theta, \phi, \gamma < 1$ reflect the size of the home externalities, and the last term in (3) allows us to formalize the connectivity between regions by means of spatial weight terms, w_{ij} . As for the spatial parameters of the model, we assume that these terms are positive, the spatial-weight matrix is row-normalized $\sum_{j=1}^N w_{ij} = 1 \quad \forall i = 1, \dots, n$ and $w_{ij} = 0$ if $i = j$. The parameter ρ represents the regional technological interdependence, with $0 < \rho < 1$.

The technological knowledge depends on the level of private, public and human capital of the own region as well as its neighbour regions.

Inserting (3) into the production function per worker (2), we have:

$$y_{it} = \Omega k_{it}^{\alpha_K + \theta} p_{it}^{\alpha_P + \phi} h_{it}^{\alpha_H + \gamma} \prod_{j=1}^N k_{jt}^{\theta \rho w_{ij}} p_{jt}^{\phi \rho w_{ij}} h_{jt}^{\gamma \rho w_{ij}} \quad (4)$$

Equation (4) represents the output per worker incorporating the knowledge spillovers and allowing us to relate the per worker output in region i to the capital investment in the same region and its neighbours.⁷ With respect to this specification it is worth highlighting that changes in

⁶ A direct extension of the function used by Ertur and Koch (2007) and Fischer (2011) would be $A_{it} = \Omega k_{it}^{\theta} p_{it}^{\phi} h_{it}^{\gamma} \prod_{j=1}^N A_{jt}^{\rho w_{ij}}$, which provides an equivalent solution to the model in (3) since in both cases it is assumed that the exogenous common knowledge Ω is the same for all regions.

⁷ If we set $\theta = \phi = \gamma = 0$ there would be no spillover effects and the per worker production function would be characterized by $y_{it} = \Omega k_{it}^{\alpha_K} p_{it}^{\alpha_P} h_{it}^{\alpha_H}$, which represents a world with closed economies.

output can be due to variations in the own capital stocks and in the stocks from the rest of the regions.

2.2 Dynamical transitions and steady state in the Neoclassical Growth Model

The neoclassical growth model assumes that labour in region i grows at rate n_i . On the other hand, it is assumed that constant shares of income, s_i^K , s_i^P and s_i^H are invested in private, public and human capital and those rates of investment are given exogenously, while these stocks depreciate at the same rate δ .⁸

We introduce the capital accumulation equations following Mankiw et al. (1992), in the case of human capital, and Barro (1990) and Bajo-Rubio (2000) for disaggregating physical capital into private and public. This induces the following dynamic equations for k_{it} , p_{it} and h_{it} .

$$\dot{k}_{it} = s_i^K (1 - \tau) y_{it} - (n_i + \delta) k_{it} \quad (5)$$

$$\dot{p}_{it} = s_i^P \tau y_{it} - (n_i + \delta) p_{it} \quad (6)$$

$$\dot{h}_{it} = s_i^H \tau y_{it} - (n_i + \delta) h_{it} \quad (7)$$

where τ is the size of the public sector, s_i^K , s_i^P and s_i^H are the fractions of income invested in private, public and human capital, respectively.⁹ The dots above the capital variables denote derivatives with respect to time.

In the steady state, private, public and human capital grow at a constant rate g :

$$\frac{\dot{k}_{it}}{k_{it}} = g \quad \frac{\dot{p}_{it}}{p_{it}} = g \quad \frac{\dot{h}_{it}}{h_{it}} = g \quad (8)$$

Substituting the dynamic equations (5)-(7) into (8) and solving, we get the capital-output ratios:

$$\frac{k_{it}^*}{y_{it}^*} = \frac{s^K (1 - \tau)}{n_i + g + \delta} \quad (9)$$

$$\frac{p_{it}^*}{y_{it}^*} = \frac{s^P \tau}{n_i + g + \delta} \quad (10)$$

$$\frac{h_{it}^*}{y_{it}^*} = \frac{s^H \tau}{n_i + g + \delta} \quad (11)$$

with the asterisk representing the steady state levels.

⁸ The Solow model assumes exogenous savings, contrary to what happens in the expansion performed in the Ramsey-Cass-Koopmans model. This limitation does not prevent us from obtaining the steady state solution and deriving the convergence equation allowed by their determinants.

⁹ The budget constraint of the public sector is given by $\tau y_{it} = c_i^P \tau y_{it} + s_i^P \tau y_{it} + s_i^H \tau y_{it}$, where c_i^P is the share of public consumption, and $c_i^P + s_i^P + s_i^H = 1$.

Inserting these expressions back into the production function per worker with the technological knowledge (4) and solving for the output:

$$y_i^* = \Omega^{\frac{1}{1-\eta}} \left(\frac{s_i^K (1-\tau)}{n_i + g + \delta} \right)^{\frac{\alpha_K + \theta}{1-\eta}} \left(\frac{s_i^P \tau}{n_i + g + \delta} \right)^{\frac{\alpha_P + \phi}{1-\eta}} \left(\frac{s_i^H \tau}{n_i + g + \delta} \right)^{\frac{\alpha_H + \gamma}{1-\eta}} \prod_{j=1}^N \left(\frac{s_j^K (1-\tau)}{n_j + g + \delta} y_j^* \right)^{\frac{\theta \rho w_{ij}}{1-\eta}} \left(\frac{s_j^P \tau}{n_j + g + \delta} y_j^* \right)^{\frac{\phi \rho w_{ij}}{1-\eta}} \left(\frac{s_j^H \tau}{n_j + g + \delta} y_j^* \right)^{\frac{\gamma \rho w_{ij}}{1-\eta}} \quad (12)$$

with $\eta = \alpha_K + \alpha_P + \alpha_H + \theta + \phi + \gamma$.

We can group exponentials and get the following expression for output per worker in the steady state:

$$y_i^* = \Omega^{\frac{1}{1-\eta}} \left(\frac{(s_i^K)^{\alpha_K + \theta} (1-\tau)^{\alpha_K + \theta} (s_i^P)^{\alpha_P + \phi} (s_i^H)^{\alpha_H + \gamma} (\tau)^{\alpha_P + \alpha_H + \phi + \gamma}}{(n_i + g + \delta)^\eta} \right)^{\frac{1}{1-\eta}} \prod_{j=1}^N \left(\frac{(s_j^K)^\theta (1-\tau)^\theta (s_j^P)^\phi (s_j^H)^\gamma (\tau)^{\phi + \gamma}}{(n_j + g + \delta)^{\theta + \phi + \gamma}} (y_j^*)^{\theta + \phi + \gamma} \right)^{\frac{\rho w_{ij}}{1-\eta}} \quad (13)$$

Taking logarithms we obtain the following expression:

$$\begin{aligned} \ln y_i^* &= \frac{1}{1-\eta} \ln \Omega + \frac{\alpha_K + \theta}{1-\eta} \ln s_i^K + \frac{\alpha_P + \phi}{1-\eta} \ln s_i^P + \frac{\alpha_H + \gamma}{1-\eta} \ln s_i^H \\ &+ \frac{\alpha_K + \theta}{1-\eta} \ln(1-\tau) + \frac{\alpha_P + \alpha_H + \phi + \gamma}{1-\eta} \ln(\tau) - \frac{\eta}{1-\eta} \ln(n_i + g + \delta) \\ &+ \frac{\theta}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln s_j^K + \frac{\phi}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln s_j^P + \frac{\gamma}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln s_j^H \\ &+ \frac{\theta}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln(1-\tau) + \frac{\phi + \gamma}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln(\tau) \\ &- \frac{\theta + \phi + \gamma}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln(n_j + g + \delta) \\ &+ \frac{\theta + \phi + \gamma}{1-\eta} \rho \sum_{j=1}^N w_{ij} \ln y_j^* \end{aligned} \quad (14)$$

2.3 Conditional convergence

Our model predicts that income per worker converges to its steady state. To obtain the convergence equation, we take differences in the logarithmic transformation of production function per worker:

$$\begin{aligned} \frac{d \ln y_{it}}{dt} &= (\alpha_K + \theta) \frac{d \ln k_{it}}{dt} + (\alpha_P + \phi) \frac{d \ln p_{it}}{dt} + (\alpha_H + \gamma) \frac{d \ln h_{it}}{dt} \\ &+ \theta \rho \sum_{j=1}^N w_{ij} \frac{d \ln k_{jt}}{dt} + \phi \rho \sum_{j=1}^N w_{ij} \frac{d \ln p_{jt}}{dt} + \gamma \rho \sum_{j=1}^N w_{ij} \frac{d \ln h_{jt}}{dt} \end{aligned} \quad (15)$$

where $\frac{d \ln k_{it}}{dt}$, $\frac{d \ln p_{it}}{dt}$, $\frac{d \ln h_{it}}{dt}$, $\frac{d \ln k_{jt}}{dt}$, $\frac{d \ln p_{jt}}{dt}$ and $\frac{d \ln h_{jt}}{dt}$ are the differences in the logarithmic transformations of capital per worker.

Inserting (4) into the dynamic equations in (5) – (7) and dividing by the corresponding capital, we obtain:

$$\frac{\dot{k}_{it}}{k_{it}} = s_i^K (1 - \tau) \Omega k_{it}^{-(1-\alpha_K-\theta)} p_{it}^{(\alpha_P+\phi)} h_{it}^{(\alpha_H+\gamma)} \prod_{j=1}^N k_{jt}^{\theta \rho w_{ij}} p_{jt}^{\phi \rho w_{ij}} h_{jt}^{\gamma \rho w_{ij}} - (n_i + \delta) \quad (16)$$

$$\frac{\dot{p}_{it}}{p_{it}} = s_i^P \tau \Omega k_{it}^{(\alpha_K+\theta)} p_{it}^{-(1-\alpha_P-\phi)} h_{it}^{(\alpha_H+\gamma)} \prod_{j=1}^N k_{jt}^{\theta \rho w_{ij}} p_{jt}^{\phi \rho w_{ij}} h_{jt}^{\gamma \rho w_{ij}} - (n_i + \delta) \quad (17)$$

$$\frac{\dot{h}_{it}}{h_{it}} = s_i^H \tau \Omega k_{it}^{(\alpha_K+\theta)} p_{it}^{(\alpha_P+\phi)} h_{it}^{-(1-\alpha_H-\gamma)} \prod_{j=1}^N k_{jt}^{\theta \rho w_{ij}} p_{jt}^{\phi \rho w_{ij}} h_{jt}^{\gamma \rho w_{ij}} - (n_i + \delta) \quad (18)$$

The main result in our model is the existence of diminishing returns to the reproducible capital: $\partial(\dot{k}_{it}/k_{it})/\partial k_{it} < 0$, $\partial(\dot{p}_{it}/p_{it})/\partial p_{it} < 0$ and $\partial(\dot{h}_{it}/h_{it})/\partial h_{it} < 0$. When a region increases its capital per worker, the rate of growth decreases and converges to its own steady state. However, an increase in capital per worker in a neighbouring region j increases the production in economies i if $\partial(\dot{k}_{it}/k_{it})/\partial k_{jt} > 0$, $\partial(\dot{p}_{it}/p_{it})/\partial p_{jt} > 0$ and $\partial(\dot{h}_{it}/h_{it})/\partial h_{jt} > 0$, and positive technological interdependence is observed. Therefore, the convergence result is still valid under the hypothesis

$$(\alpha_K + \alpha_P + \alpha_H) + \frac{\theta + \phi + \gamma}{1 - (\theta \rho + \phi \rho + \gamma \rho)} < 1,$$

in contrast with endogenous growth models, where the marginal productivity in capital is constant.

As in the literature, the transitional dynamics can be quantified by using a log linearization of equations (5) – (7) around the steady state. These assumptions allow us to simplify the convergence equation in (22):

$$\frac{d\ln y_{it}}{dt} = -\lambda_{it}[\ln y_{it} - \ln y_i^*], \quad (19)$$

where λ represents the speed of convergence. Following Ertur and Koch (2007) and Fischer (2011), solving the first order differential equation in (19) and subtracting the income per worker at some initial date $\ln y_{it-T}$

$$\frac{\ln y_{it} - \ln y_{it-T}}{T} = -\frac{(1-e^{-\lambda_{it}})}{T} \ln y_{it-T} + \frac{(1-e^{-\lambda_{it}})}{T} \ln y_i^* \quad (20)$$

This model predicts convergence, due to the fact that growth of real income per worker is a negative function of income at initial date. Therefore, poor economies grow faster than rich ones, indicating convergence in economic growth, after controlling for the determinants of the steady state. For this reason, we obtain the expression that allows us to contrast the existence of conditioned convergence, or convergence of economies to their own steady states.

Finally, substituting the income per worker in the steady state we can rewrite this equation for region i :

$$\begin{aligned}
\frac{\ln y_{it} - \ln y_{it-T}}{T} = & -\frac{(1 - e^{-\lambda_{it}})}{T} \ln y_{it-T} + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{1}{1 - \eta} \ln \Omega + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\alpha_K + \theta}{1 - \eta} \ln s_i^K \\
& + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\alpha_P + \phi}{1 - \eta} \ln s_i^P + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\alpha_H + \gamma}{1 - \eta} \ln s_i^H + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\alpha_K + \theta}{1 - \eta} \ln(1 - \tau) \\
& + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\alpha_P + \alpha_H + \phi + \gamma}{1 - \eta} \ln(\tau) - \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\eta}{1 - \eta} \ln(n_i + g + \delta) \\
& + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\theta + \phi + \gamma}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln y_{j,t-T} + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\theta}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln s_j^K \\
& + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\phi}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln s_j^P + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\gamma}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln s_j^H \\
& + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\theta}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln(1 - \tau) + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\phi + \gamma}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln(\tau) \\
& - \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\theta + \phi + \gamma}{1 - \eta} \rho \sum_{j=1}^N w_{ij} \ln(n_j + g + \delta) \\
& + \frac{(1 - e^{-\lambda_{it}})}{T} \frac{\theta + \phi + \gamma}{1 - \eta} \rho \sum_{j=1}^N \frac{1}{(1 - e^{-\lambda_{it}})} w_{ij} [\ln y_{jt} - \ln y_{jt-T}]
\end{aligned} \tag{21}$$

The convergence equation in expression (21) allows contrasting conditioned convergence on income and its determinants. Here, the growth of income per worker is a negative function of the initial level of income per worker, after controlling for the determinants of the steady state. More specifically, the growth rate of income per worker depends positively on physical investment, private and public, and human capital, and negatively on its own labour growth. Also, the growth in income per worker is a function of the same variables in neighbouring economies because of technological interdependence. We can observe that the income growth is higher in economies with less initial income, indicating the existence of convergence, although the growth rate is higher, the larger the initial income in neighbouring economies. Finally, this is qualified by the last term in (21) indicating that income growth in a region also depends on its neighbour's income growths.

In what follows we contrast empirically the effectiveness of this spatially augmented neoclassical model with public sector in Spanish regions. Then, we will show how the technological interdependence as well as public and human capital can influence convergence in economic growth. Additionally, since we have introduced fiscal policy, we can analyse the tax income effect and the existence of fiscal spillovers in Spanish regions.

3. Determinants of convergence: empirical evidence

3.1 Econometric specification and methods

The empirical contrast of the convergence equation in (21) is performed on the basis of the following Spatial Durbin Model:

$$\begin{aligned}
 \ln y_{it} - \ln y_{it-1} = & \beta_0 - \beta_1 \ln y_{it-1} + \beta_2 \ln s_{it}^K + \beta_3 \ln s_{it}^P + \beta_4 \ln s_{it}^H + \beta_5 \ln \tau_{it} \\
 & - \beta_6 \ln(n_{it} + g + \delta) + \rho_1 W \ln y_{it-1} + \rho_2 W \ln s_{it}^K + \rho_3 W \ln s_{it}^P + \rho_4 W \ln s_{it}^H + \rho_5 W \ln \tau_{it} \\
 & - \rho_6 W \ln(n_{it} + g + \delta) + \rho_7 W \ln[\ln y_{it} - \ln y_{it-1}] + u_{it}, \\
 u_{it} = & \eta_i + v_{it},
 \end{aligned} \tag{22}$$

where $\frac{(1-e^{-\lambda_{it}})}{T} \frac{1}{1-\eta} \ln \Omega = \beta_0$, β_k and ρ_k are the $(k \times 1)$ vectors of parameters to be estimated.

The two components error term u_{it} includes a vector of regional effects η_i and a vector of identically and independently distributed disturbance terms v_{it} . It is assumed that η_i and v_{it} are independent of each other and of the regressors matrix. The $N \times N$ spatial weight matrix W defines dependence across N regions along T periods. In our study, the spatial interdependence is based on the consideration of a physical contiguity matrix, in which its elements would be 1, for two bordering regions, and 0 for all others. Since contiguity does not change, the spatial weight matrix W for one period is the same for all time periods. The row-normalization of W implies that $\sum_j^N w_{ij} = 1$. These matrices specify physical proximity as the main driver for the presence of spillovers.

In the estimation of equation (22) we consider spatial panel econometric techniques that allow us to introduce specific heterogeneities (Baltagi, 2008). We base our estimation on the spatial fixed effects estimation, which is the most extended and appropriate specification in order to introduce those regional heterogeneities. We focus on the fixed effects spatial two stage least squares estimator (FE-S2SLS) by Baltagi and Liu (2011) on the basis of Kelejian and Prucha (1998) and maximum likelihood fixed effects estimator (ML-FE), following Millo and Piras (2012).¹⁰ Additionally, we check robustness comparing the obtained results with the standard methods in the literature of spatial models based on a spatial error component model, with

¹⁰ This estimation method is based on the instruments proposed by Kelejian and Prucha (1998), taking X , WX , and WX^2 as exogenous variables.

random effects, which is the most general and appropriate specification to make unconditional inferences on the population based on a sample (Beenstock and Felsenstein, 2007). We present in the appendix the robustness check using the spatial error component best two stage least squares estimator (SEC-B2SLS), provided by Baltagi and Liu (2011). This estimation method extends Baltagi's (1981) error component two-stage least square estimator, following the method introduced by Kelejian and Prucha (1998) and using Lee's (2003) optimal instruments for this spatial autoregressive panel model.

3.2 Databases: description and sources

The proposed convergence equation is estimated using individual information on 47 Spanish provinces (NUTS 3) from 1980 to 2011. Data came from two main statistical sources: Gross Domestic Product (GDP) and private labour (number of employees) from the *Instituto Nacional de Estadística* (Spanish National Statistics Institute - INE). The series of productive (i.e., non-residential) private capital (K), public capital (P) and human capital (H) are taken from the database compiled by Mas et al. (2011) at the *Instituto Valenciano de Investigaciones Económicas* (IVIE) constructed using a perpetual inventory method. The tax income is included in the database on the public sector (*Las diferencias regionales del sector público español* – Regional differences in the Spanish public sector) also drawn up by the IVIE. All variables are expressed in 2005 constant values.

Income is expressed in per capita terms, while the capital investment represents the share of income invested in private, public and human capital; the latter corresponds to economic value of human capital.¹¹ Furthermore, the size of the public sector is introduced in terms of the fiscal policy, which is analysed through tax revenues. Finally, the labour growth rate includes technological growth and depreciation rates.¹² Table 1 shows the descriptive statistics corresponding to variables used in the analysis.

¹¹ The economic value of human capital is estimated taking into account the salary that a firm would be willing to pay according to the productivity associated with an education level, in line with the methodology proposed by Mulligan and Sala-i-Martin (1997) and Mulligan and Sala-i-Martin (2000).

¹² As is standard in the growth literature, we take $g + \delta$ to be equal to 0.05 for all provinces and years (Mankiw et al., 1992).

Table 1: Descriptive statistics

Variables	Mean	Standard deviation	Minimum	Maximum
Income per worker: y	39,596.83	7,720.32	15,214.09	62,221.68
Private Capital: s^K	21.52	35.89	1.29	363.27
Public Capital: s^P	26.30	35.78	2.11	307.01
Human Capital: s^H	34.13	39.44	3.81	255.83
Tax Income: τ	0.13	0.07	0.03	0.49
Labour Growth: $n + g + \delta$	0.06	0.04	<0.001	0.42

Source: own elaboration

3.3 Determinants of convergence: evidence from Spanish provinces

We analyse the contribution of public policies on convergence introducing spatial interactions. The period of time used is of special interest given that it coincides with an increase in the decentralization of public functions as Spain joined the European Community. Both events gave rise to substantial growth in public investment intended to improve public infrastructure, while the whole tax and revenue system was perfected so as to match European guidelines.

Results following panel data analysis techniques are shown in table 2. The statistics for joint significance and R^2 show that the estimation is significant. The model has been estimated by means of the fixed effects estimator so as to capture unobservable heterogeneity (Baltagi, 2008), because this is more efficient according to the results observed in both the F test of individual effects and Hausman's test (Hausman, 1978). Looking at the results shown, we observe a process of convergence in income per capita during the period considered. Private capital and income tax jointly contribute to economic growth in Spanish provinces. The public capital and human capital coefficients are negative, as for labour growth. Therefore, we can conclude for the basic specification of the convergence equation without knowledge spillovers that private capital and fiscal policies contribute positively to economic growth and territorial cohesion in Spanish provinces. This result is similar to those observed in the literature. In this sense, Rodriguez-Pose and Bwire (2004) analysed where the different effects of public expenditure on economic growth could be attributed to decentralization of authority in several countries, and specifically the negative effect observed in Spain.

Table 2: Convergence equation estimation results

$\ln y_{it} - \ln y_{it-1}$	Fixed Effects Model
Constant (c)	0.131 (11.003)***
$\ln y_{it-1}$	-0.010 (-10.947)***
$\ln s_{it}^K$	0.004 (7.927)***
$\ln s_{it}^P$	-0.002 (-3.248)***
$\ln s_{it}^H$	-0.009 (-10.334)***
$\ln \tau_{it}$	0.002 (3.409)***
$\ln(n_i + g + \delta)$	-0.002 (-16.142)***
Implied speed of convergence λ	0.009
Joint Significance Test F	F(6,1404) = 72.076
R^2	0.235
Individual Effects Test F	F(46,1040) = 2.428
Hausman Test	$\chi^2(6) = 98.519$
Observations	1,457

*T-statistic in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$ Source: own elaboration*

Next, we analyse the impact of public investment on physical and human capital and fiscal policies on regional cohesion allowing for the possibility of spatial interdependence between provinces. Results following spatial panel data analysis techniques are shown in Table 3. Wald statistics of joint significance show that the equation estimated is significant.

Looking at the results reported in Table 3 we can see how the popular fixed effects spatial panel two stage least squares estimator (FE-S2SLS) and the maximum likelihood fixed effects estimator (ML-FE) yield similar results.¹³ These results show robustness, in comparison with those obtained in some other research papers, in which they estimate convergence equations following spatial econometric techniques. For instance, Arbia et al. (2008) analyse

¹³ See appendix for a robustness check. In appendix we show the results obtained through the error component best two stage least squares estimator (SEC-B2SLS) by Baltagi and Liu (2011). In compare with the estimations by fixed effects, those results differ in the spillover effects corresponding to labour growth and economic growth. Therefore, considering the error component model, in which the regional unobservable heterogeneities are random effects, the sign and magnitude of spillover effects associated with labour and income per capita in adjacent provinces differ in comparison with the fixed effects model.

β -convergence linked to the Neoclassical Growth Model in a set of NUTS 2 EU regions, concluding that the model implied by the cross-sectional approach differs from panel data models. In line with this literature, Pfaffermayr (2009) contrasts beta and sigma convergence in NUTS 3 EU regions during 1980-2002 and shows a low speed of convergence. In our case, the estimations obtained from spatial panel techniques, FE-2SLS and ML-FE estimators are similar.

Table 3: Spatial estimation results

$\ln y_{it} - \ln y_{it-1}$	<i>FE-2SLS</i>	<i>ML-FE</i>
Constant (<i>c</i>)	-0.008 (-0.238)	
$\ln y_{it-1}$	-0.045 (-13.129)***	-0.041 (-26.298)***
$\ln s_{it}^K$	-0.002 (-1.799)*	-0.002 (-2.861)**
$\ln s_{it}^P$	0.001 (0.629)	0.001 (0.925)
$\ln s_{it}^H$	-0.025 (-11.887)***	-0.023 (-23.134)***
$\ln \tau_{it}$	0.003 (1.916)*	0.003 (3.204)***
$\ln(n_i + g + \delta)$	-0.001 (-5.706)***	-0.002 (-12.522)***
$W \ln y_{it-1}$	0.045 (9.836)***	0.038 (20.844)***
$W \ln s_{it}^K$	0.002 (1.385)	0.004 (4.795)***
$W \ln s_{it}^P$	-0.001 (-0.499)	-0.002 (-2.153)*
$W \ln s_{it}^H$	0.027 (6.932)***	0.021 (13.731)***
$W \ln \tau_{it}$	-0.003 (-1.484)	-0.002 (-1.939)
$W \ln(n_i + g + \delta)$	0.001 (2.068)***	0.000 (0.4788)
$W[\ln y_{it} - \ln y_{it-1}]$	1.026 (4.372)***	0.467 (16.545)***
Implied speed of convergence λ	0.044	0.040
Wald test	$\chi^2(13) = 316.942$	
Observations	1,457	1,457

Notes: *T*-statistic in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. FE-2SLS = Fixed Effects Spatial Two Stage Least Squares Estimator, Baltagi and Liu (2011). ML-FE = Maximum Likelihood Fixed Effects Estimator, Mollo and Piras (2012).

Source: own elaboration

We observe convergence in income per worker with an implied speed of convergence λ of 4%, although the spillover effects on income level and growth are positive. Therefore, the income level and the economic growth of neighbouring provinces positively affect economic growth. The values of spillover effect on income level coefficient for both estimators are 0.045

and 0.038 respectively. Furthermore, the coefficient associated to spillover effect of income per worker growth is more intense, with a wide range of coefficient values from 1.026 to 0.467. Therefore, these results show that the income per worker growth in other provinces is more intense than the income level per worker, in accordance with other studies using Spanish provincial data (Baños et al., 2012; Tortosa-Ausina et al., 2005). This can be explained by the fact that having richer provinces as neighbors benefits economic activity since this contributes to intensifying economic interactions with those provinces.

In the case of private capital, there is a direct negative effect on growth, but the spillover effect is positive, indicating that the positive effect from private investment in physical capital comes from neighbour provinces rather than internal investment. We can observe the same phenomenon regarding public investment in human capital. Some research works argue that human capital, as educational attainment, contributes to divergence due to the unequal distribution and educational policies in Spanish provinces (Serrano, 1998).¹⁴ In the present study we considered human capital as an economic value of public investment. So, this result indicates the fact that very high investment levels in education in several provinces benefits other provinces, and in particular those that are nearest.

The contribution of public capital is not significant. In general, in the literature public capital has a positive effect on income growth due to its indirect effect, reflecting that economic activity benefits from public investment located in the nearest provinces. Particularly, Mas et al. (1995) estimate convergence equations for the 17 Spanish regions for the 1955–1991 period, concluding that public capital had a significant role in the convergence process, with a coefficient of 0.005. Furthermore, Mas et al. (1998) discuss the existence of convergence among Spanish regions during the period from 1964 to 1993 and the importance of public capital endowments in explaining Total Factor Productivity (TFP), with an elasticity of 0.1107. We can conclude that public investment in physical capital doesn't affect economic growth and convergence during the period considered, in line with some other research works who point out the importance of decentralization and the quality and efficiency of institutions (Rodriguez-Pose and Bwire, 2004). Nevertheless, fiscal policies exhibit a notable effect on economic growth. Regarding tax income, we can observe a direct positive effect, indicating that higher financial support for public

¹⁴ Castelló and Domenech (2002) obtain similar results introducing the Gini distribution of education in a convergence equation for 108 countries over five-year intervals from 1960 to 2000.

activities results in internal benefits. These results are in line with those obtained by Srithongrung and Kriz (2014) for the US continental states.

Finally, it is worth noting that the overall effect on labour growth is negative, with the direct effect predominating over the indirect positive effect. This would be an indirect corroboration of the existence of agglomeration economies drawing production factors to locations with larger economic activity and whose growth is reinforced; this, in turn, contributes to intensifying divergence and constitutes the main proposition of theories explaining core-periphery patterns (Barbero and Zofío, 2012).

These results confirm the existence of notable spillover effects in human capital and income level per worker and growth. Nevertheless, Montañés and Olmos (2014) identify the existence of different convergence patterns between north and south in Spanish provinces. They suggest that the speed of convergence in income differs among provinces situated in the North and the South of Spain using econometric techniques based on unit root techniques to the human development index and the per capita GDP. In order to test this hypothesis and obtain a stability analysis of the intensity of this impact we divided the provincial data by their income level.¹⁵ So, with this aim in mind, we performed a stability analysis of the effects on investment rates by groups of provinces using Chow's test of structural change (Chow, 1960). The results are shown in table 4.

As shown in Table 4, we performed the estimation of the convergence equation with knowledge spillover effects, including a dummy variable for the group of high-income provinces and the interaction between investment rates and the dummy variable representing high-income level provinces. As before, we followed the same estimation methods based on the spatial fixed effects method so as to present comparable results. We observed that the coefficients associated to investment rates corresponding to all provinces and the high-income group level changed sign, allowing us to confirm the existence of different impacts between high and low income level provinces. Therefore, the significance of the coefficients associated to the investment rates in high-income provinces allow us to corroborate the existence of structural changes in the effects of these variables by groups of provinces according to the Chow test performed.

¹⁵ Low-income provinces correspond to those provinces with income levels below the median and high-income provinces to those above.

Table 4: Spatial estimation results with stability analysis of investment

$\ln y_{it} - \ln y_{it-1}$	<i>FE –2SLS</i>	<i>ML –FE</i>
Constant (c)	0.006 (0.328)	
$\ln y_{it-1}$	-0.043 (-20.629)***	-0.039 (-24.596)***
$\ln s_{it}^K$	-0.003 (-3.336)***	-0.003 (-4.174)***
$\ln s_{it}^K$ high income per worker provinces	0.002 (2.459)**	0.003 (4.288)***
$\ln s_{it}^P$	0.002 (2.276)**	0.002 (2.772)**
$\ln s_{it}^P$ high income per worker provinces	-0.003 (-3.023)***	-0.003 (-4.044)***
$\ln s_{it}^H$	-0.025 (-19.986)***	-0.023 (-23.409)***
$\ln s_{it}^H$ high income per worker provinces	0.001 (1.884)*	0.001 (1.269)
Group of high income per worker provinces (dummy)	-0.001 (-0.952)	-0.001 (-0.911)
$\ln \tau_{it}$	0.003 (2.682)***	0.002 (2.787)**
$\ln(n_i + g + \delta)$	-0.001 (-9.723)***	-0.001 (-12.340)***
$W \ln y_{it-1}$	0.043 (16.194)***	0.037 (19.725)***
$W \ln s_{it}^K$	0.002 (2.427)**	0.003 (4.608)***
$W \ln s_{it}^P$	-0.001 (-0.853)	-0.001 (-1.932)
$W \ln s_{it}^H$	0.025 (11.364)***	0.019 (13.067)***
$W \ln \tau_{it}$	-0.002 (-1.955)*	-0.002 (-1.671)
$W \ln(n_i + g + \delta)$	0.001 (3.036)***	0.000 (0.379)
$W[\ln y_{it} - \ln y_{it-1}]$	0.876 (8.189)***	0.457 (16.157)***
Implied speed of convergence λ	0.042	0.038
Wald test	$\chi^2(13) = 924.295$	
Observations	1,457	1,457

Notes: *T*-statistic in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. FE-2SLS = Fixed Effects Spatial Two Stage Least Squares Estimator, Baltagi and Liu (2011). ML-FE=Maximum Likelihood Fixed Effects Estimator, Millo and Piras (2012).

Source: own elaboration

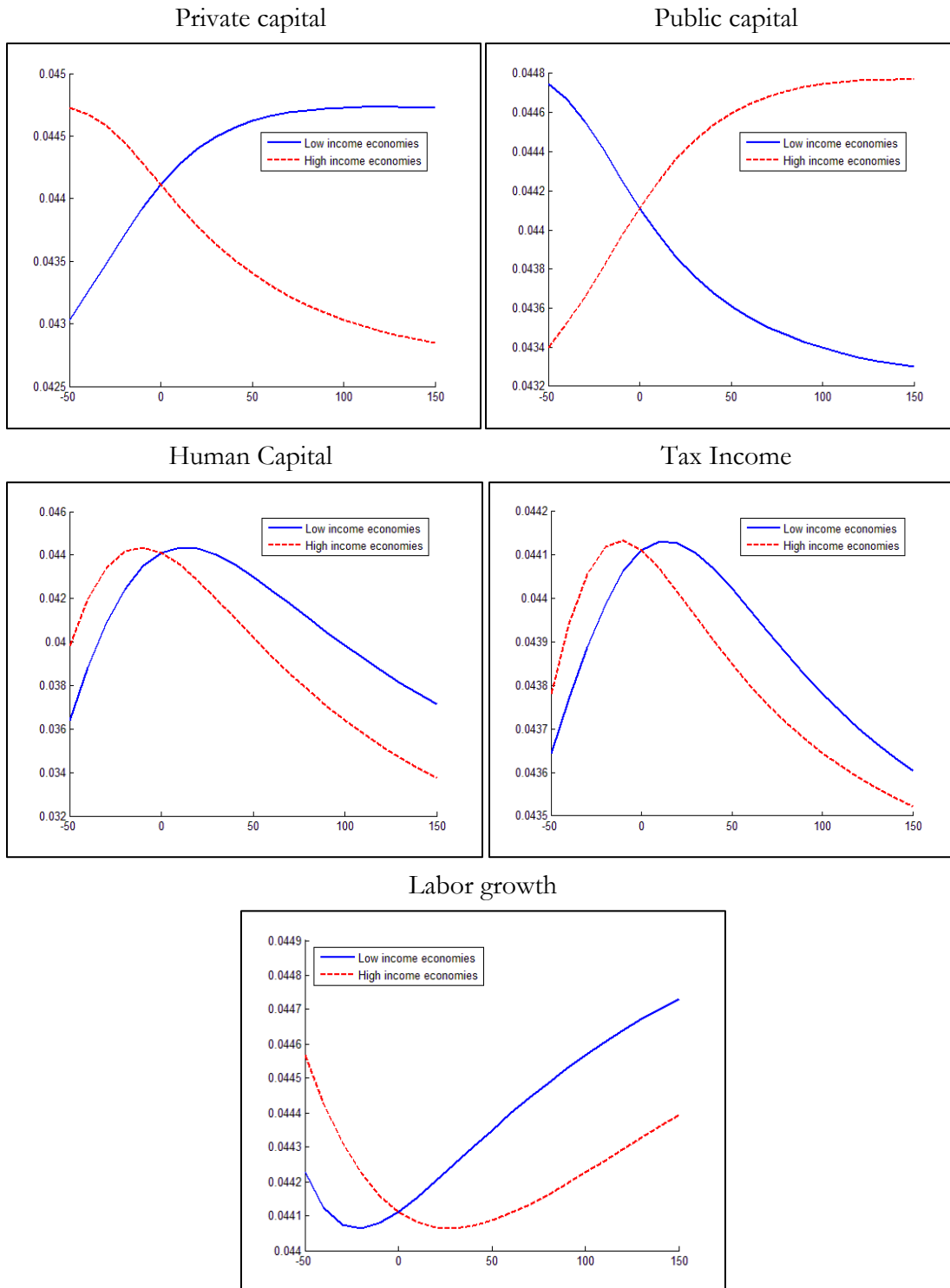
Finally, we performed the same analysis but focusing on the sensitivity of speed of convergence with respect to the changes in the explanatory variables. We analysed the marginal contribution of determinants to speed of convergence dividing the sample according to the provincial income level, in order to explore the effect of the different policy instruments on cohesion.

Figure 1 presents the result of the estimated speed of convergence when the investment rates, tax income and labour growth are increasing, starting with negative rates of growth. The graph shows that private capital investment contributes to improving the speed of convergence in low-income economies, and reduces convergence in rich provinces. When we consider public investment rates in physical capital we obtain different results. In this case, the public investment improves convergence in rich economies. A further noteworthy result can be seen if we take into account human capital, tax income and labour growth, in which rich and poor economies exhibit identical behaviour. Human capital and tax income reduce convergence when the growth rates are positive, while labour growth improves convergence for rates greater than -25% for poor provinces and 25% in rich economies, favouring economic growth and regional cohesion.

We can conclude by analysing the marginal effects: firstly, that labour growth improves regional cohesion and that physical capital investment rate helps to promote convergence through its positive effect depending on the group of provinces. Private investment favours convergence between poor economies and public investment reduces disparities between rich economies. So, this argument could encourage private and public investment in physical capital. By contrast, education and fiscal policies increase disparities in income per capita.

In the previous analysis we obtained some interesting results, especially regarding the impact of spillover effects in human capital, income level and income growth. We conclude that, firstly, human capital positively affects neighbouring provinces. This result indicates that very high investment levels in education in several provinces benefit the others, and in particular, the nearest provinces. A further interesting result is that spillover effects in income level and income growth generate a positive impact on economic growth, improving regional cohesion and contributing to reduce disparities in income per capita between provinces. Finally, we can observe that dividing the sample into two groups of provinces, rich and poor economies, private investment and economic value of human capital affect high income level economies positively while the impact of public investment on economic growth is negative. The signs differ from those obtained for all economies. Therefore, we can corroborate the existence of structural changes in the effects of investment rates by groups of provinces according to the performed Chow test.

Figure 1: Contribution to speed of convergence



Source: own elaboration

4. Concluding remarks and policy implications

In this article we analyse the convergence in Spanish regions during the period 1980–2011, extending the neoclassical growth model with public sector and fiscal policies, and incorporating knowledge spillovers in the production process by taking into account spatial interactions. With this aim in mind, we perform empirical contrasts on the basis of novel spatial econometric techniques recently proposed in the literature, and that introduce these spatial spillovers as determinants of convergence. We make use of new programming routines that allow the implementation of these approaches in MATLAB.

Results show strong evidence of convergence in economic growth and, therefore, a reduction in economic disparities. Moreover, the spillover effects on the regions' income levels and growth are positive. Consequently, we confirm that the level of economic activity of neighbouring provinces positively affects the development of a given geographical area. This can be explained by the fact that having richer neighbouring provinces can benefit a region's economic activity since this contributes to intensifying the commercial relations with those provinces. In the case of private capital, there is a direct negative effect on growth, but the spillover effect is positive, indicating that the positive effect from private investment in physical capital comes from neighbouring provinces instead of internal investment. We can observe the same phenomenon regarding public investment in human capital. This result points to the fact that very high investment levels in education in several provinces benefit other provinces, especially those nearest. A further interesting result is that, regarding tax income, we can observe a direct positive effect, indicating that public financial support results in internal benefits.

Finally, we can observe that dividing the sample into two groups of provinces, rich and poor economies, private investment and economic value of human capital affects high income level economies positively, while the impact of public investment on economic growth is negative. Therefore, we can corroborate the existence of structural changes in the effects of investment rates by groups of provinces according to the performed Chow test.

Additionally, this methodology has allowed us to evaluate the marginal effects of regressors on the speed of convergence. Convergence can be fostered by promoting investment in private physical capital given its accelerating effect on the speed of the catching-up process in poor provinces. Moreover, considering public policies oriented to increase public investment, it is worth highlighting that there is a growth rate from which improvements in investment in high-income economies contribute to enhance the speed of convergence. Given this result, the better

option is orienting public investment efforts on rich economies. Conversely, tax revenues and investment rates on education intensify disparities. As a result, from these analyses we conclude that fiscal policies do affect economic growth and regional cohesion in different and even opposing ways: sometimes contributing in direct and indirect ways, and sometimes being detrimental. Finally, labour growth contributes favourably to the speed of convergence.

These findings have important implications for policy makers that can be qualified for low- and high-income regions. In fact, our results also show that it is necessary to take into account the departing income levels when determining the positive effects of public investment on economic growth and regional cohesion. While investing in human capital has positive effects across all regions, this is not the case of investment in public capital and tax revenues, where high-income economies tend to benefit most from the former and low-income economies from the latter. Finally, the spatial nature of the effects should not be overlooked; for instance, fiscal policy proxied by tax revenues contributes to economic growth, which intensifies competition between regions for public resources that would allow disparities to be reduced by reallocating the financial support from the public administration to the poorest economies.

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Appendix: Robustness Check

Table A.1: Spatial estimation results

$\ln y_{it} - \ln y_{it-1}$	<i>SEC-B2SLS</i>
Constant(c)	0.04031 (4.0167) ***
$\ln y_{it-1}$	-0.00543 (-5.7727)***
$\ln s_{it}^K$	0.00083 (1.3301)
$\ln s_{it}^P$	-0.00029 (-0.4945)
$\ln s_{it}^H$	-0.00059 (-1.5676)
$\ln \tau_{it}$	0.00050 (1.3188)*
$\ln(n_i + g + \delta)$	-0.00204 (-12.9423)***
$W \ln y_{it-1}$	0.00090 (0.7133)
$W \ln s_{it}^K$	0.00250 (3.0133) ***
$W \ln s_{it}^P$	-0.00232 (-2.9015) ***
$W \ln s_{it}^H$	-0.00063 (-0.9980)
$W \ln \tau_{it}$	-0.00059 (-1.1287)
$W \ln(n_i + g + \delta)$	-0.00275 (-7.0693)***
$W[\ln y_{it} - \ln y_{it-1}]$	-1.24155 (-7.4941)***
Implied speed of convergence λ	0.039
Wald test	$\chi^2(13) = 409.956$
Observations	1,457

Notes T-statistic in parenthesis. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. SEC-B2SLS = Spatial Error Component Best Two Stage Least Squares Estimator, Baltagi and Liu (2011).