Regional disparities and technology transfers in Spain

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Abstract. This paper explores the growth patterns of the Spanish regions in the period 1959-98. Its objetive is to test the neoclassical model using Spanish regional data. The model is simulated and estimated and observed series are compared. The test consist of three phases: 1) we check the relative importance of the productive inputs in the Spanish regional convergence process, with special attention to the Solow residual; 2) we analyze the model's capacity to explain the observed income per capita differences in a given year and 3) we study whether, given the initial state, the model can reproduce the dynamics of the variables.

We prove that the technological factor is the most important explanatory variable for regional differences both in a given year and through time. The predictions of the Neoclassical model with the same exogenous growth rate for all the regions are clearly rejected by the data. On the other hand, a model with different exogenous rates for each region or a model with a process of exogenous imitation can reproduce the observed sigma convergence process in labor productivity. A deeper analysis of the total factor productivity series, however, makes us reject the existence of a constant exogenous rate or a continuous process of technological imitation. Lastly, we estimate the speed of convergence for observed and estimated series and calculate the downward biased when we assume that the Spanish regions have the same exogenous growth rate.

KEYWORDS: Neoclassical model, technology transfers, regional differences, convergence and panel data regressions.

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The main purpose of this paper is *to present the stylized facts of the Spanish regional convergence process during the period 1965-95* and *to test the neoclassical model from a regional perspective*. Despite the progress made by the economic growth literature over the last decades, little is known about the relative importance of the main factors responsible for the regional convergence process in Spain. This, among other effects, complicates the comparison between different models, which is constrained to focus on the rate at which an economy converges to its own steady state through cross-section regressions (prominent examples are: Barro and Sala-i-Martín (1991), Mankiw, Romer and Weil (1992), Islam (1995) or Lee, Pesaran and Smith (1997)).

We test the neoclassical model using a different point of view. We center our attention on the capacity of the model to reproduce the observed series. The test is based on the simulation of the model and the comparison between the observed and estimated series. The model testing consists of two phases. The first one analyzes the possibility that the regional disparities in a given year can be the result of differences in the basic parameters of the model. In the second, we study the temporal evolution of the regional series and whether, given the initial conditions, they can be reproduced by the model.

Our conclusions are derived from a basic result:

- Technology is the most critical factor behind regional income per capita disparities, *both in a given year and through time*.

Although the neoclassical model can explain the observed labor productivity differences in a given year once we account for differences in the level of total factor productivity, the observed dynamics reject the neoclassical model with the same exogenous growth rate for all the regions.

On the other hand, allowing for different exogenous rates for each region or a process of imitation results in sigma convergence values similar to those observed in reality, confirming for the Spanish regions the conclusions obtained by Lee, Pesaran and Smith (1997) for the international framework. *The regional evidence can be reproduced by the neoclassical model if we allow for the existence of different exogenous rates or a process of imitation.* A deeper analysis of the total factor productivity growth rates, however, rejects the existence of 'constant' exogenous rates or a continuous process of imitation. Periods of high income per capita growth rates are periods of higher total factor productivity growth rates and imitation between regions, while periods of low income per capita growth rates are associated with lower technology rates and the lack of imitation.

From the calculation of the panel data regressions for the observed and estimated labor productivity series, we also conclude that not allowing for differences in the technological dynamics results in biased estimations for the speed of convergence.

The article is divided in four parts. *The first part analyzes the decomposition of the income per capita variance in its three components*: the total factor productivity, the capital/labor ratio and the labor/total population ratio. To the extent that we associate technology with total factor productivity, *our results underline the high importance of the technological factor both in a given year and through time*. The observed convergence in income per capita is mostly caused by the total factor productivity convergence -expressed as the Solow residual- instead of convergence in the capital/labor ratio, the main variable of the neoclassical model.

The differences in income per capita in 1995 do not depend on the capital/labor ratio. In this year, the correlation between the capital/labor ratio and the regional income per capita is zero or even negative. Besides, an important part of the convergence process cannot be explained by the evolution of the productive inputs, physical capital and labor.

By contrast with a model in which only different initial technological levels are assumed for each region, these results suggest the notion of technological catch-up implying that the estimation of the speed of convergence through fixed effect panel regression methods is biased (Lee et al. (1997)).

The possibility of different initial technological levels is already noted in Islam (1995) or Mankiw, Romer and Weil (1992), but, in our case, we also find that the total factor productivity disparities change through time. Hall and Jones (1995), Lee et al. (1997) or De la Fuente (1997), among others, point out this idea. Lee et al. (1997) emphasizes the possibility of different growth rates, but still within the neoclassical framework.

The second part of the paper studies the capacity of the neoclassical model to reproduce the available data. We start with the analysis of the regional ranking in a given year and end with the dynamic simulation of the models.

Again, we find that *the Spanish regional data can only be the result of a convergence process in which the evolution of the total factor productivity has played a key role*. The neoclassical model with the same exogenous rate for all the regions is totally rejected. On the other hand, the predictions of a model with different rates or with imitation are in line with the observed dynamics in labor productivity sigma convergence but present two important problems: a) first is the rejection of a constant exogenous rate or a continuous process of imitation and the exogeneity that we have applied to our selection of a different 'constant' exogenous rate for each region; and b) second is the estimated drastic change in the long-run ranking for the labor productivity. The estimated ranking places regions like Extremadura or Castilla la Mancha inside the three richest regions of Spain, and in the technological frontier, while regions like Madrid or Baleares fall to the end of the list, the opposite to the present situation. The inability of the model to provide a convincing explanation for the regional differences in the exogenous rates calls for further investigation. The inputs, physical capital and labor, cannot explain the observed income per capita differences both in a given year and through time.

Given the previous results, *in the third part of the article we analyze the dynamic of the total factor productivity growth rates.* Our conclusions depend on the way we add temporally the growth rates. When we allow for shorter periods, the analysis rejects the existence of a 'constant' exogenous rate or a continuous process of imitation. Therefore, both a model with different exogenous rates and a model with imitation are rejected in the short run.

In the fourth part we compare, for different variables, the speed of convergence from panel data and $\beta-$convergence regressions for the observed and estimated series. *We conclude that allowing for different regional dynamics for the technology factor increases the speed of convergence* obtaining values that are compatible with a normally accepted value for the capital share.

The remainder of the paper consist of six sections. In the first section, we present the construction of the series. In the second section, we calculate the income per capita variance decomposition. In the third section, we analyze the estimated ranking in the balanced growth path. In the fourth section, we compare three models, the neoclassical model with the same, with different exogenous rates and with exogenous imitation. In the fifth section, we study the dynamics of the technology factor. In the sixth and last section, we compare the speed of convergence estimations for the estimated and observed data.

1. Construction of the data set

The original data sources are "Renta Nacional de España y su Distribución Provincial. Serie homogenea 1955-93" (biannual data), "Renta Nacional de España y su Distribución Provincial 1993. Avance 1994-95" (biannual data) and "El Stock de Capital en España y sus Comunidades Autónomas" (annual data, 1964-95, Mas et al. (1998)), the three of them published by the BBVA Foundation.

The correlation between all the variables, both in levels and growth rates, and the income per capita levels and growth rates is presented in the Appendix A.

Labor/total population ratio: the number of filled jobs is divided by the total population for each region.

Income per capita (YP, 1955-95): the Gross Value Added at factor cost, deflated by the implicit price index[1], is divided by the total population for each region.

Labor productivity (LP, 1955-95): We divide the deflated Gross Value Added by the total number of filled jobs in each region.

Capital/labor ratio (K/L, 1965-95): the net capital stock from Mas et al. (1995) is divided by the total number of filled jobs:

$$K/L = \frac{K_t^P + K_t^{Pu}}{L_t}$$

[1]We use the implicit regional price index of the Gross Value Added at factor cost from "Renta Nacional de España y su Distribución Provincial".

where $K_t^P + K_t^{Pu}$ refers to the net private capital stock plus the net public capital stock.

Capital/output ratio (K/Y, 1965-95):

$$K/Y = \frac{K_t^P + K_t^{Pu}}{GVA_t}$$

Labor share (LS, 1955-95): LS is calculated as

$$\begin{aligned} LS_t &= \frac{RT_t + LS_t \cdot RM_t}{GVA_t} \\ &\implies LS_t = \frac{RT_t}{GVA_t - RM_t} \end{aligned}$$

where RT refers to the labor income and RM to the mixed income[2]. RT belongs completely to the labor factor while the proportion of RM belonging to each factor is unknown. We assume RM is shared as the labor share.

Real wage (W, 1955-95):

$$W_t = \frac{RT_t + LS_t \cdot RM_t}{L_t}$$

Rate of return to capital (r, 1965-95):

$$r_t = \frac{GVA_t - RT_t - LS_t \cdot RM_t - D_t}{K_t^P + K_t^{Pu}}$$

where D_t refers to the aggregate capital consumption for each region, "Renta Nacional de España y su Distribución Provincial".

The net capital stock has been inflated using the regional investment price index from Mas et al. (1995). We maintain the numerator at current pesetas. The objective is to obtain a rate of return with no unit of measure[3].

Total factor productivity (TFP, 1965-95)

The growth rate of the TFP is the growth rate of the Solow residual.

$$(1-\alpha_{jt})\,\gamma_{jt}^{TFP} = \gamma_{jt}^{GVA} - \alpha_{jt}\gamma_{jt}^{K} - (1-\alpha_{jt})\gamma_{jt}^{L}$$

where α_{jt} represents the capital share of the region j in the year t.

To calculate the relative TFP levels in 1965, we use two different methods.

Mode 1: we follow the equation[4]

$$TFP_j = TFP_{AN} \cdot \left(\frac{GVA_j}{GVA_{AN}}\right)^{\left(\frac{1}{1-\alpha_j}\right)} \cdot \left(\frac{K_{AN}}{K_j}\right)^{\left(\frac{\alpha_j}{1-\alpha_j}\right)} \cdot \left(\frac{L_{AN}}{L_j}\right)$$

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[2]The GVA at factor cost consist of five items: labor income, mixed income, capital income, public administration income and aggregate capital consumption.

[3]If we deflate the numerator by the GVA deflator index, we obtain "Consumer bundles/machines" as our unit of measure.

[4]See Escriba and Murgui (1998).

where AN refers to Andalucía, the numerarie region[5].

Mode 2: we apply, for each region j, the formula

$$TFP_j = (GVA_j)^{\left(\frac{1}{1-\alpha_j}\right)} \cdot (K_j)^{\left(\frac{-\alpha_j}{1-\alpha_j}\right)} \cdot \left(\frac{1}{L_j}\right)$$

Capital / effective labor ratio (KLE, 1965-95): K/L is divided by the TFP (Mode 1).

2. Income per capita variance decomposition

In this section we measure the relative influence of the productive inputs on the observed income per capita (YP) convergence. De la Fuente (1998) decomposes YP in three items: the labor productivity, the unemployment rate and the participation rate. Its main result is the high importance of the labor productivity differences in the explanation of the YP variance.

In our work, we take one step further including the stock of physical capital in our analysis. Our aim is to measure the different weights of the TFP and the capital/labor ratio in the explanation of the YP variance. We want to explicit underline the role played by the TFP. This is the basic principle behind our article and represents the necessity to introduce different TFP regional dynamics. Using a different procedure, Maudos, Pastor and Serrano (2000) study the relative influence of the technological and productive efficiency changes over the Spanish convergence process. They find that the two variables contribute positively to the regional convergence process.

We assume a Cobb-Douglas production function. YP consists of three components: the labor / total population ratio, the capital / labor ratio and the total factor productivity.

$$\frac{Y_{it}}{P_{it}} = \frac{L_{it}}{P_{it}} \cdot \left(\frac{K_{it}}{L_{it}}\right)^{\alpha_{it}} \cdot A_{it}^{1-\alpha_{it}}$$

where $\frac{Y_{it}}{P_{it}}$ is the YP of the region i in the year t, A_{it} is the TFP, $\frac{K_{it}}{L_{it}}$ is the capital / labor ratio, α_{it} is the capital share and $\frac{N_{it}}{P_{it}}$ is the labor / total population ratio.

From the previous identity, we can decompose YP variance in six different components: the technological differences, the differences in the capital / labor ratio, the differences in the labor / total population ratio and the correlations between these three components.

[5]The initial level of the region of Andalucia is given by

$$TFP_{AN} = GVA_{AN}^{\left(\frac{1}{1-\alpha_{jAN}}\right)} \cdot K_{AN}^{\left(\frac{-\alpha_{jAN}}{1-\alpha_{jAN}}\right)} \cdot \left(\frac{1}{L_{AN}}\right)$$

TABLE 1. Proportion of each component over income per capita variance.

	Mode 1		Mode 2	
	1965	1995	1965	1995
(TFP)^2	0.3904	0.3919	0.3512	0.4093
(K/L)^2	0.1373	0.1171	0.1373	0.1171
(L/P)^2	0.1197	0.3521	0.1197	0.3521
(TFP)*(K/L)	0.1727	-0.1604	0.0889	-0.2312
(TFP)*(L/P)	0.2452	0.4463	0.1734	0.3543
(K/L)*(L/P)	0.1294	-0.0017	0.1294	-0.0017
TOTAL	1.1947	1.1453	1	1

$$
\begin{aligned}
\sum_{i=1}^{N}\left(\ln\frac{Y_{it}}{P_{it}}-\mu_{YPt}\right)^2 &= \sum_{i=1}^{N}\left((1-\alpha_{it})\cdot\ln A_{it}-\mu_{(1-\alpha)At}\right)^2 + \\
&+\sum_{i=1}^{N}\left(\left(\alpha_{it}\cdot\ln\frac{K_{it}}{L_{it}}\right)-\mu_{\alpha KLt}\right)^2+\sum_{i=1}^{N}\left(\ln\frac{L_{it}}{P_{it}}-\mu_{LPt}\right)^2 + \\
&+2\sum_{i=1}^{N}\left((1-\alpha_{it})\cdot\ln A_{it}-\mu_{(1-\alpha)At}\right)\cdot\left(\left(\alpha_{it}\cdot\ln\frac{K_{it}}{L_{it}}\right)-\mu_{\alpha KLt}\right) + \\
&+2\sum_{i=1}^{N}\left((1-\alpha_{it})\cdot\ln A_{it}-\mu_{(1-\alpha)At}\right)\cdot\left(\ln\frac{L_{it}}{P_{it}}-\mu_{LPt}\right) + \\
&+2\sum_{i=1}^{N}\left(\left(\alpha_{it}\cdot\ln\frac{K_{it}}{L_{it}}\right)-\mu_{\alpha KLt}\right)\cdot\left(\ln\frac{L_{it}}{P_{it}}-\mu_{LPt}\right)
\end{aligned}
\tag{2.1}
$$

where μ refers to the average of the variable[6].

Tables 1 and 2 reproduce each component in a given year and through time. From table 1 we highlight two basic results:

- *the great importance of the total factor productivity in the explanation of the income per capita variance.* In 1965, the TFP variance alone explains around 35% of the YP variance. If we also add the correlation values between the TFP and the other two variables we get more than 60%. Furthermore, this component is still important in 1995 with values of 41% and 53%, respectively.
- *the increase in the relative weight of the labor market differences and the reduction in the weight of the capital/labor ratio differences.* The percentage of the YP variance explained by the labor/total population ratio variance rises from 12% and 44% in 1965 to 35%

[6]The equality is inexact when we apply the TFP series as calculated in Mode 1.

TABLE 2. Income per capita variance decomposition. Changes over time.

Mode 1

	65-79	79-95	65-75	75-85	85-95
(Y/P)^2	-0.93	0.04	-0.66	-0.20	-0.02
(TFP)^2	-0.21	-0.13	-0.10	-0.09	-0.15
(K/L)^2	-0.11	-0.03	-0.05	-0.09	0.00
(L/P)^2	-0.03	0.12	-0.03	0.09	0.02
(TFP)*(K/L)	-0.31	-0.12	-0.10	-0.40	0.06
(TFP)*(L/P)	-0.34	0.29	-0.32	0.17	0.10
(K/L)*(L/P)	-0.17	-0.05	-0.12	-0.15	0.05

Mode 2

	65-79	79-95	65-75	75-85	85-95
(Y/P)^2	-0.93	0.04	-0.66	-0.20	-0.02
(TFP)^2	-0.14	-0.13	-0.10	0.03	-0.19
(K/L)^2	-0.11	-0.03	-0.05	-0.09	0.00
(L/P)^2	-0.03	0.12	-0.03	0.09	0.02
(TFP)*(K/L)	-0.22	-0.12	-0.07	-0.32	0.04
(TFP)*(L/P)	-0.25	0.25	-0.30	0.24	0.05
(K/L)*(L/P)	-0.17	-0.05	-0.12	-0.15	0.05

and 70% in 1995, representing a relative increase in the importance of the labor differences. For the capital/labor ratio these percentages are 14% and 44% in the year 1965, and 12% and a negative value in 1995, which constitutes a fall in its relative weight.

The only analysis of the relative levels of the factors in a given year hides the path followed through time.

Table 2 summarizes the convergence dynamics into five periods for the six components and the YP variance.

During the period 1965-79 the change in the TFP, and in the correlation of the TFP with the other two components, as a percentage of the income per capita variance change, is over a 60%. If we consider the period 1965-75, this figure increases to 71%. Therefore, we cannot assume just the existence of different technological steady states. *The steady states and the composition of the regional income per capita variance in the steady states change through time.*

This relation, however, disappears in the period 1979-95 where we observe a slight increase in the YP variance influenced by the increase in $\frac{N_{it}}{P_{it}}$ and the correlation between $\frac{N_{it}}{P_{it}}$ and the TFP. The rest of the series reduce their variances.

2.1. Role of the capital/labor ratio. A great part of the convergence process depends on the variables: TFP and $\frac{N_{it}}{P_{it}}$. On the other hand, the neoclassical model places the evolution of the capital/labor ratio as the main factor in the convergence process. What are the characteristic features of the pattern followed by this ratio?

As we observe in Table 2, the overall YP convergence process is positively influenced by the evolution of the capital/labor ratio, although its relative importance is much lower than that of the TFP. In the future, however, the reduction in the capital/labor ratio differences will not have a positive influence. Since 1985 the correlation between the income per capita and the capital/labor ratio is negative, with a value lower than -0.2 for the year 1995. *The regional differences in income per capita in the year 1995 are not related to differences in the capital/labor ratio.*

This fact is clearly against the long run predictions of most economic growth models. In the case of persistent differences in income per capita that are not totally explained by differences in the labor/total population ratio, growth models predict the existence of a long-run positive correlation between the income per capita and the capital/labor ratio. However, as we show in the Appendix C, this fact can be predicted in the medium-run (40 years) by a model with different exogenous growth rates for each region or by models in which the technological dynamic is a key factor.

The correlation between the capital/labor ratio and the income per capita is zero in 1993. In this year, there are still important differences in the regional income per capita level that are not totally explained by differences in the labor markets. Besides, technological differences, measured by the Solow residual, have a large weight in the explanation of income per capita differences. From these results, the speed of convergence estimations obtained through fixed effect panel regression methods should present a significant bias (see Lee et al. (1997)). We will examine below the differences between the speeds obtained from data and those resulting from the series of the models (section 6).

2.2. Choice of the capital share. How do these results depend on the choice of the capital share?

To answer this question, we compute for different capital shares the σ convergence value of the residual(table 3):

$$res = \ln(labor\ productivity) - \alpha \cdot \ln(capital/labor\ ratio)$$

where we assume that α is the same for all regions and we calculate the sigma convergence statistic as the standard deviation of the log of res.

A 'non-constant' dynamic for the sigma convergence is observed for all possible values of α*.* The sigma convergence value decreases from 1965 to 1995 with this fall being more important in the period 1965-79.

Values for the capital share close to zero imply greater differences between the σ convergence values in the years 1965 and 1995. On the other hand, higher values of the capital share result in a greater reduction in the period 1965-79 and a higher value for the σ convergence of the residual in 1995.

TABLE 3. σ-convergence of the residual. Values of the capital share between 0 and 1.

		alpha										
		0	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1**
Variation in sigma	**1965-79**	-0.066	-0.064	-0.062	-0.060	-0.060	-0.060	-0.061	-0.064	-0.067	-0.071	-0.075
	1979-95	-0.055	-0.044	-0.034	-0.023	-0.012	-0.001	0.009	0.019	0.028	0.035	0.042
	1965-95	-0.121	-0.108	-0.095	-0.083	-0.072	-0.061	-0.052	-0.045	-0.039	-0.035	-0.033
Value of sigma	**1965**	0.241	0.228	0.216	0.206	0.197	0.189	0.184	0.181	0.181	0.182	0.187
	1995	0.120	0.120	0.121	0.123	0.125	0.128	0.132	0.136	0.142	0.147	0.153

The fall in the σ value of the residual depends negatively on the value of α, varying from an 18% fall for α=1 to a 50% fall for α=0. The part of the labor productivity $\sigma-$convergence explained by the residual varies from a 27% for α=1 to a 100% for α=0 with a 69% for α=0.3[7].

Therefore, we conclude that *technology is a critical factor behind regional income per capita disparities for all possible values of the capital share.*

3. Regional ranking in the balanced growth path

In the previous section we concluded that the TFP plays a key role in the convergence process. In the following sections we test whether the observed series can be reproduced by the neoclassical model. We conclude that in order to replicate the observed convergence process, it is necessary to allow for a different TFP regional dynamic.

Our analysis of the capacity of growth models to reproduce the empirical evidence consist of two parts. In the first part, we analyze the differences between the estimated and the observed regional ranking for a given year. In our case, the reference year is the last one of the sample period, where we assume that the economies have reached the balanced growth path. In the second part, we study whether the models can reproduce the observed dynamic changes and, if the answer is affirmative, what assumptions are needed for it.

In what follows, we simulate the neoclassical model allowing for regional differences in some of the parameters, and compare the estimated ranking in the balanced growth path with the observed KLE ranking in 1995[8].

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[7] The calculation is made without considering the influence of the correlation between the residual and the capital / labor ratio.

[8] The value of the KLE for the region of Madrid was 2.8 times the ratio of the region of Castilla la Mancha in 1995. This figure represents a clear symptom of the failure of the neoclassical model with the equality of all the parameters except the initial technological

Table 4. Calibrated parameters

Parameters	Value
β	0.95
δ	0.06
σ	2.546
n	0
g	0.028
CS	0.35
ρ	-0.35

Jones (1997) performs a similar exercise for the international framework finding a positive correlation of 0.96 between the observed 1990 world income distribution and the estimated distribution. His model includes also the accumulation of human capital.

Our methodology draws on the standard neoclassical model setup. The social planner chooses the sequences of consumption $\{c_t\}_{t=0}^{\infty}$ and stock of physical capital $\{k_t\}_{t=0}^{\infty}$ per worker that maximize the discounted value of the stream of utility, subject to the law of motion of the stock of capital per worker and the budget constraint. The problem can be specified as:

$$Max \sum_{t=0}^{\infty} \beta^t \frac{c_t^{1-\sigma} - 1}{1-\sigma} \tag{3.1}$$

$$c_t + (1+n) \cdot k_{t+1} - (1-\delta) \cdot k_t = \left[(1-\alpha) A_t^{\rho} + \alpha \cdot k_t^{\rho}\right]^{\frac{1}{\rho}}$$

$$A_{t+1} = A_t \cdot (1 + g_j)$$

$$k_0 \text{ and } A_0 \text{ given}$$

where small letters denote quantities per worker and we assume constant elasticity of substitution production and utility functions.

Definition 1. *A Balanced Growth Path (b.g.p.) for this economy is a solution* $\{c(t),k(t)\}_{t=0}^{\infty}$ *to the optimization problem (3.1) for some initial condition* k_0 *and* A_0 *such that c(t) and k(t) grow at a constant rate.*

The parameters to be calibrated for this economy are β, σ, δ, n, ρ, α, CS (capital share), k_0, A_0 and g. In practice it is very difficult to determine the b.g.p. values for the parameters. We use regional data as a proxy for their b.g.p. value.

For the case of equality of the parameters, the reference values are the ones presented for the aggregate framework in Arévalo (2002), displayed in Table 4.

The value that takes k_0 and A_0 does not influence the results obtained for the estimated ranking, as we study directly the capital/effective labor

level. Differences in the intial technological level cannot be the only determinant factor of the income per capita differences.

ratio[9]. We also assume throughout the analysis that β, σ *and* δ *are equal for all the regions*[10]. Therefore, we center our attention on the variations of the regional ranking resulting from disparities in the parameters n, ρ, α, CS and g.

3.1. Parameter variation. We allow for variations in g_j, n_j, α_j and ρ_j. The first two parameters, g_j and n_j, refer to the average over time of the annual compounded growth rates for the period 1965-95 of the TFP and L, respectively[11].

To obtain the regional differences of the other two parameters, we follow the next procedure:

- *Different capital shares.*

: Given g_j, we find α and the equilibrium capital / effective labor ratio as the solutions to the following system of equations:

Euler equation in the b.g.p.

$$\left[(1-\delta)+\left(1-\alpha_j+\alpha_j\cdot\hat{k}_{jt}^{*\rho}\right)^{\frac{1}{\rho}-1}\cdot\alpha_j\cdot\hat{k}_{jt}^{*\rho-1}\right]=\frac{((1+g_j)\cdot(1+n_j))^{\sigma}}{\beta} \tag{3.2}$$

Labor share in 1995

$$LS_{j1995}=\frac{(1-\alpha_j)}{(1-\alpha_j)+\alpha_j\cdot\hat{k}_j^{*\rho}} \tag{3.3}$$

where LS_{j1995} refers to the labor share of the region j in the year 1995.

- *Variability in the elasticity parameter* ρ of the CES production function. To obtain a different value ρ for each region we need to add a new equation. This corresponds to the labor share in 1965.

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[9] The value of A_0 and k_0, however, can indeed affect the observed KLE ranking.

[10] $\beta = 0.95$ is taken exogenously. $\delta = 0.06$ is the depreciation rate assumed for the design of the aggregate stock of physical capital series for Spain. σ is obtained from the Spanish aggregate data from the Euler equation for consumption:

$$\left(\frac{c_t}{c_{t-1}}\right)^{\sigma}=\beta\cdot(1+r_t)$$

where r_t is the rate of return on aggregate capital and $\frac{c_t}{c_{t-1}}$ the growth rate of the aggregate consumption at constant pesetas (Instituto Nacional de Estadística). Calculating the average of the growth rates of c_t and r_t for the period 1985-99, we obtain

$$(1.0216)^{\sigma}=1.0559$$

and a value of $\sigma = 2.546$ (see Arévalo (2002)).

[11] The data presents a biannual periodicity. To calculate the annual compounded growth rate (ACGR) for the variable x, we calculate:

$$(1+ACGR_t)=\sqrt{\frac{x_t}{x_{t-2}}}$$

Expressing the capital/effective labor ratio in 1965 as a proportion of the equilibrium ratio(ratio in 1995), we obtain the values of α_j, ρ_j and $\hat{k}_j^*$ using 3.2, 3.3 and 3.4.

Labor share in 1965

$$PL_{j1965} = \frac{(1-\alpha_j)}{(1-\alpha_j) + \alpha_j \cdot \left(pro \cdot \hat{k}_j^*\right)^{\rho_j}} \tag{3.4}$$

where *pro* refers to the proportion of the initial ratio $\hat{k}$ over the b.g.p. ratio[12].

3.2. Results. Table 5 presents the correlation between the observed and the estimated ranking under different assumptions about parameter variation. A model that allows for regional differences in all the parameters results in erroneous predictions for the long run ranking (a correlation of 0.2). On the other hand, the model that adjusts better the regional ranking in the b.g.p. contains only differences in the growth rates of the labor force, reaching a correlation value with the observed ranking close to 0.7. Therefore, we conclude that once we account for a different A_0 for each region *the neoclassical model can reproduce the labor productivity differences in a given year.*

The correlation decreases to 0.6 when we allow for different exogenous rates. Differences in just the capital share results in a correlation of only 0.32.

A model with the same exogenous rates replicates the differences in a given year at least as well as a model with different exogenous rates, a correlation of 0.7 against a correlation of 0.6.

4. Simulation.

In this section, we compare the transitional dynamics of the four models: mod1) the same parameters except for the initial technological level(A_0); mod2) different exogenous growth rates(g_j); mod3) different exogenous rates and factor elasticity of substitution (ρ_j) and mod4) the same exogenous rates but with technology imitation. We assume throughout different capital shares(CS_j) and labor growth rates(n_j).

We test wether, given the initial state, the models can replicate the observed convergence dynamic. We conclude that *the empirical evidence can be reproduced by the neoclassical model if we allow for different exogenous rates for each region or a process of technology imitation.*

[12] The value of ρ cannot be calculated for three regions: Cantabria, Navarra and País Vasco. In these regions, given the observed change in the capital share from 1965 to 1995, the variation of the capital/effective labor ratio is lower than expected . Their value is assumed to be equal to -1.39 (the lowest value).

In the other hand, Extremadura presents a positive ρ. The capital share has decreased while the capital/effective labor ratio increased.

TABLE 5. Correlation between the estimated and observed capital/effective labor ratio ranking in the b.g.p.. Different assumptions about the parameters.

	Steady State								
	Model								Observed
	Cobb-Douglas			CES					
	Differences in n.	Differences in n and g.	Differences in CS, n and g.	Differences in CS.	Differences in n	Differences in g.	Differences in CS, n and g.	Differences in CS, n, g and rho.	
Correlation with the observed ranking	0.69	0.58	0.60	0.32	0.76	0.57	0.59	0.22	1.00
Standard deviation of the log	0.26	0.11	0.18	0.16	0.22	0.13	0.21	0.36	0.27

Note: CS refers to the capital share, g to the TFP growth rate, n to the labor growth rate and rho to the elasticity of substitution of the CES production function.

Can we consider the existence of different g a normal assumption? Clearly, the answer to this question depends on the concept behind the idea of an exogenous growth factor and on wether we are concerned with the short or long run. If the engine of growth is the increase in the level of a common world knowledge, the normal assumption would be an uniform rate. In the other hand, if technology is not a public good or there is sectoral specialization, we should assume heterogeneous rates.

In order to distinguish the assumptions that are necessary to reproduce the regional empirics, we simulate the models. Then the estimated and observed series are compared.

We assume that the Spanish regions have reached their b.g.p. in 1995. Given the selected parameters, the economy is capable of reaching the b.g.p. in 30 years[13]. In that period, the economy covers at least 96% of the distance between the initial and the b.g.p. ratio. The maximum error is 4 points while the ratio of the region of Castilla la Mancha was three times the ratio of the region of Madrid in 1995.

4.1. The same growth rate of the technological factor. In this case, we assume $g_j = g$ for all regions j. To obtain g_j, we calculate the average, for each region, of the annual compounded TFP growth rates during the period 1965-95. g is the average of g_j. Table 4 showed the calibrated parameters for this case.

[13]See Arévalo (2002) for a test of the neoclassical model using aggregate Spanish data. Looking at two different statistics, 1) the initial values and the temporal variation of the observed and estimated series and 2) the time that is necessary to reach the balanced growth path, Arevalo (2002) concludes that the neoclassical model cannot be rejected with the available aggregate data.

TABLE 6. Proportions of the initial K/(L*TFP) ratio over the b.g.p. ratio.

	Growth rate of the technological factor	Proportion of K/(L*TFP) (0) over K/(L*TFP) (b.g.p.)
Andalucía	0.028	0.584
Aragón	0.033	0.822
Asturias	0.027	0.739
Baleares	0.015	0.411
Canarias	0.026	0.583
Cantabria	0.031	0.863
CastillaLaMancha	0.034	0.590
CastillayLeón	0.033	0.683
Cataluña	0.023	0.615
ComunidadValenciana	0.026	0.548
Extremadura	0.035	0.597
Galicia	0.033	0.648
Madrid	0.018	0.704
Murcia	0.029	0.684
Navarra	0.032	0.829
PaísVasco	0.026	0.852
Larioja	0.030	0.559
Correlation between g(j) and the proportions		0.376
Correlation with the 1995 income per capita	-0.640	-0.004
Correlation with the 1995 labor productivity	-0.511	0.256
Correlation with the 1965 income per capita	-0.778	0.157
Correlation with the 1965 labor productivity	-0.787	0.170

The simulation procedure can be divided in five steps: a) the choice of an initial condition for the maximization program, b) the simulation of the model, c) the design of the series, d) the equalization of the initial states for the observed and estimated series and e) the computation of a statistic to compare the temporal evolution of the series.

STEP 1: To simulate the path followed by each region, *the initial value of the capital /effective labor ratio in 1965 is calculated as a proportion of the ratio in 1995.* These proportions are displayed in Table 6.

The correlation between the proportions and the regional income per capita in 1965 is 0.15. This means that the distance to the balance growth path does not determine the regional wealth, or from another point of view, *the relative wealth in 1965 is not representative of the distance to the balanced growth path.*

Furthermore, we can conclude that *all the regions have their initial positions out of the b.g.p..* Only four regions present a proportion with a value over 0.8: Aragón, Navarra, País Vasco and Cantabria (highest with 0.86).

STEP 2: From these proportions, *we simulate the evolution of the capital/ effective labor ratio* for the different regions, assuming that we are on the balanced growth path at the end of the sample period.

STEP 3: To calculate the other variables, we first calculate the values of the regional TFP. The initial differences observed in the year 1965 are used as the initial values of A_{jt}[14]. Then, the values for the rest of the years are calculated using g. After obtaining the TFP and KLE ($\hat{k}$) series, the rest of the series are derived from them (see the Appendix B). These are the labor productivity, the effective labor productivity, the capital/labor ratio, the real wage, the rate of return and the labor share.

STEP 4: As we previously showed (section 3.2), the model cannot reproduce perfectly the capital/effective labor ratio ranking in the b.g.p.. Assuming that other factors affect the equilibrium ratio, *we equalize for each region the initial levels of the estimated and observed capital/effective labor ratio and effective labor productivity*[15].

This assumption is equivalent to the introduction of a different constant term for each region in the panel data estimations. It represents our relative incapacity to explain the long run income per capita differences. This simplification leaves outside variables with a potential heavy weight in regional disparities as the education or the geographical characteristics. In spite of the lost of degrees of freedom associated with the equalization of initial levels, there are still major challenges in the analysis of the transitional dynamics, and in special, the determinant factors of the process[16].

STEP 5: The last step is *the calculation of the σ convergence value* for each of the variables. $\sigma-$convergence is defined as[17]

$$\sigma_t = \sqrt{\frac{\sum_{i=1}^{N} (y_{it} - \mu_t)^2}{N}}$$

[14]The qualitative results do not change if we assume the value of the TFP in 1995 as the final condition.

[15]We follow this procedure for both the model with the same and different exogenous rates. With the aim of assuming the same initial levels of the two ratios, we made the following adjustments:

$$\begin{aligned} \hat{k}^{Obs}_{j1965} &= \hat{k}^{P'}_{j1965} = B_j \cdot \hat{k}^{P}_{j1965} \\ \hat{y}^{Obs}_{j1965} &= \hat{y}^{P'}_{j1965} = C_j \cdot \hat{y}^{P}_{j1965} \end{aligned}$$

where Obs, P and P' refers to observed, estimated and adjusted estimated, respectively. B_j and C_j are calculated for each region j and for each model. There is a negative correlation, over 0.75 in absolute value, between the values of B_j and C_j and the income per capita and labor productivity in 1965 and 1995.

[16]A great number of variables that affect the initial income per capita levels, remain relatively unchanged in the short and medium run.

[17]Véase Barro and Sala-i-Martín (1991).

where μ_t is the regional average of the variable y_{it} and N is the total number of regions. y_{it} represents the log of the variable for the capital / effective labor ratio, the capital / labor ratio, the labor productivity, the total factor productivity, the income per capita, the rate of return to capital and the real wage, consisting in the value of the variable without logs for the capital / output ratio and the labor share.

4.2. Different growth rates of the technological factor and different factor elasticity of substitution in production. Lee et al. (1997) points out the possibility not only of different initial technological levels, but also of different growth rates for the technological factor.

The difference in the simulation between a model with the same exogenous rate for all the regions, a model with different exogenous rates and the model with imitation that we will analyze below rely on the calculation made in STEP 3.

For the model with different exogenous rates we follow the previous five steps to simulate the model but assuming in the STEP 3 different exogenous rates for each region, g_j. The average of the annual compounded TFP growth rates for each region, in the period 1965-95, represent the different values of g_j. The initial value of the TFP is assumed, as previously, equal to the observed value in 1965.

Additionally, we analyze how the results change when we allow for differences in the elasticity ρ.

4.3. Technology imitation. The literature about economic growth cites the technological distance between a region and the leader as one of the main variables that influences the TFP growth rates. Longer distances imply higher rates. We search for the existence of a positive relationship between the regional TFP growth rates and the technological distance to the leader, in this case, the region of Madrid.

We simulate the path that we should have observed in the case of interregional technological transfers according to the following equation[18]

$$\gamma_{TFPj} - \gamma_{TFPM} = 0.0543 - 0.1181 \cdot \left(\frac{TFPj}{TFP_M}\right) + 0.0638 \cdot \left(\frac{TFPj}{TFP_M}\right)^2 \quad (4.1)$$

The model to be simulated is the one presented in the previous sections, assuming a technological transfer (4.1) that is exogenous to the consumer's decision problem. To obtain the series with imitation, the model is simulated using the same exogenous rate for all the regions but different capital shares and different ρ for each region[19]. Once we have obtained $\hat{k}$, we calculate the other variables using as the TFP series the ones obtained after applying the previous formula (STEP 3). Then, as in the rest of the chapter, we

[18]Column (c), model 2, table 15. See section below.

[19]We assume that the exogenous growth rate is the same for all the regions but that there are discrete exogenous jumps resulting from the imitation process.

TABLE 7. Observed and estimated σ-convergence variation (period 1965-95).

	Observed		The same g		Different g		Imitation	
	Variation	Initial level	Variation	Initial level	Variation	Initial level	Variation	Initial level
K/(L*PTF)	-0.064	0.323	-0.070		-0.067		-0.070	
Y/(L*PTF)	-0.030	0.137	-0.032		-0.031		-0.032	
K/L	-0.106	0.206	-0.044		-0.102		-0.073	
Y/L	-0.121	0.241	0.005		-0.120		-0.136	
TFP	-0.125	0.333	0.000		-0.126		-0.153	
W	-0.094	0.222	0.029	0.234	-0.098	0.234	-0.112	0.234
r	-0.057	0.241	-0.109	0.250	-0.106	0.234	-0.109	0.250
LS	-0.012	0.037	-0.008	0.031	-0.008	0.031	-0.008	0.031
Y/P	-0.096	0.318						

compare the σ-convergence values of the estimated and observed series for two models: different g and imitation.

4.4. Results. In the Figures 1 and 2, we compare the simulations for these three models. Table 7 presents the σ value changes for the period 1965-95.

We conclude the following:

- *A model with different growth rates or with imitation improves the predictions of the model with the same exogenous growth rate* in the following variables: the total factor productivity, the labor productivity, the income per capita, the capital/labor ratio and the real wage. This result underlines the key role that the evolution of the TFP performed in the Spanish regional convergence process. *To assume different growth rates allows us to link coherently the observed speed of convergence with a normally accepted value for the capital share, 0.35. A model with the same exogenous rate for all the regions predicts steadiness or a small labor productivity divergence*, something clearly different from the observed reality. The neoclassical model does not necessarily predict convergence in income per capita. Its prediction depends on the initial regional positions.
- *The models behave badly in the short run.* The observed falls in the σ convergence values for the capital / effective labor ratio and the effective labor productivity during the period 1965-80, are much greater in reality than in the model. The obtained results are based on the measurement of the σ convergence value. This, however, can be hiding different regional characteristics. Appendix D presents for each region the observed and estimated dynamic in the following variables: the capital/effective labor ratio, the effective labor productivity, the rate of return to capital and the capital/output ratio.

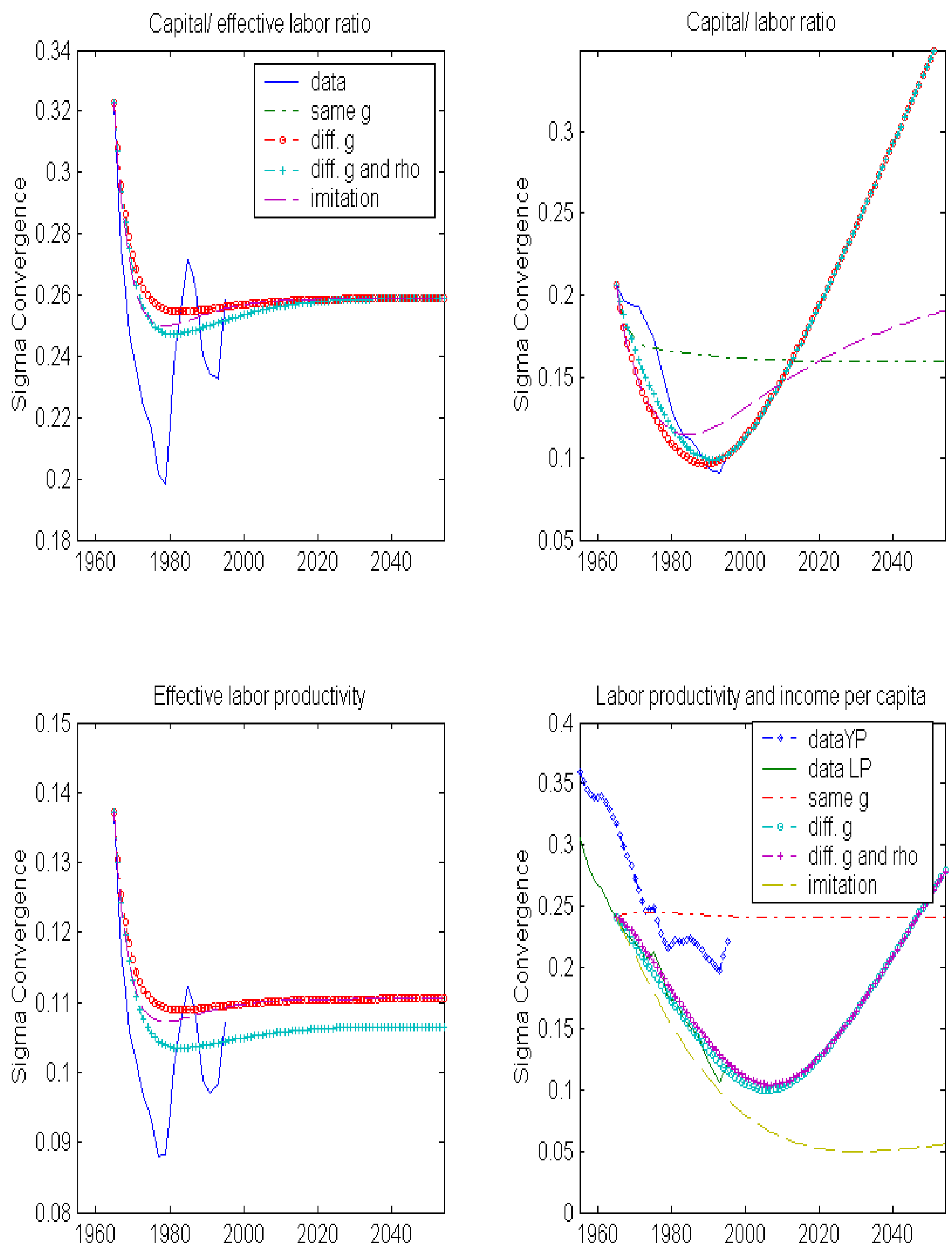

FIGURE 1. The same g, different g and imitation.

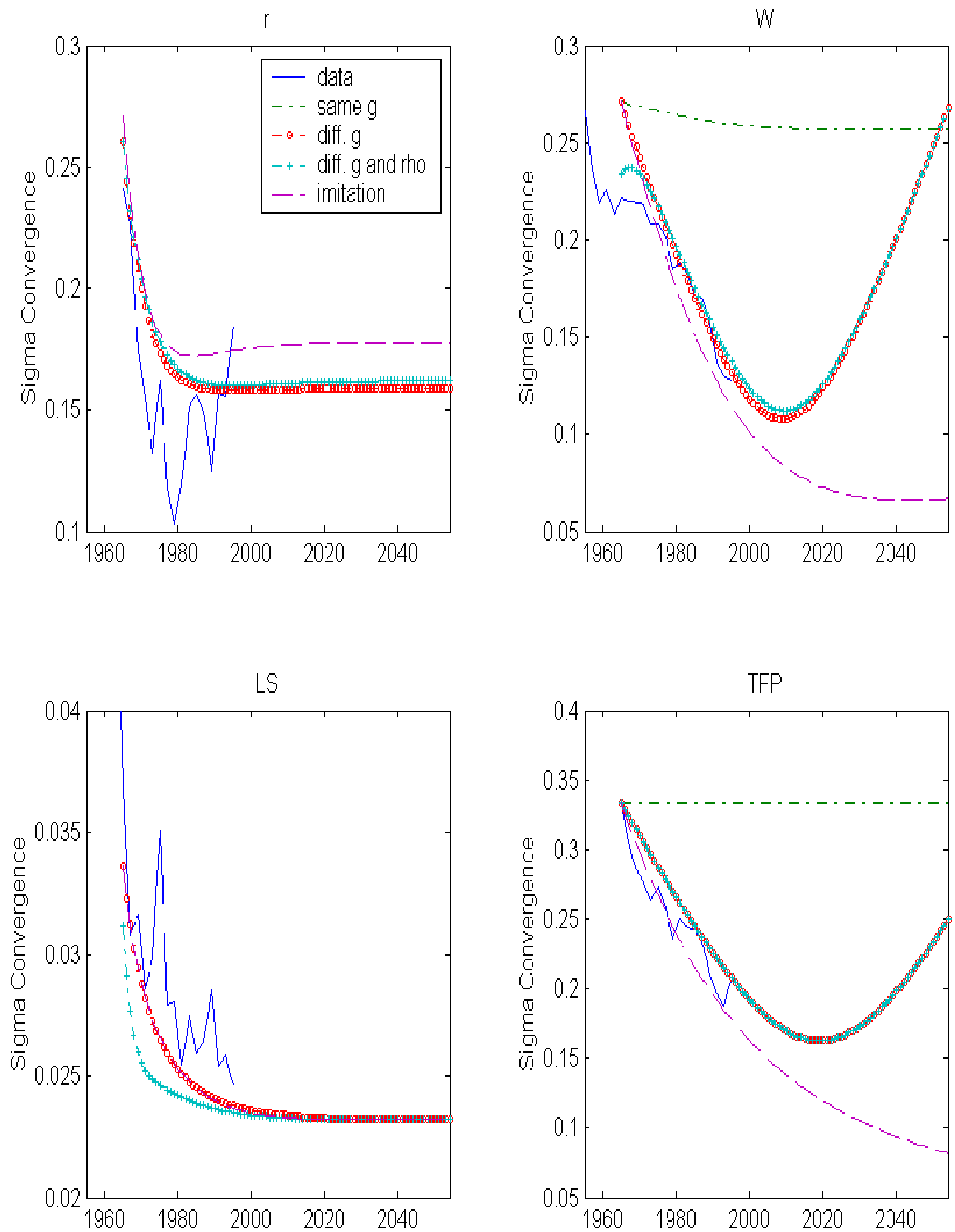

FIGURE 2. The same g, different g and imitation. (cont.)

Table 8. Correlation between the observed 1995 labor productivity ranking and the estimated ranking for different years.

	Correlation with the observed 1995 labor productivity ranking	
	Different g	Imitation
1995	1.00	0.67
2025	0.31	0.07
2055	-0.14	-0.45
2085	-0.29	-0.60

- Even though the model with different growth rates for each region or the model with imitation seems to provide a better explanation for the transitional dynamics, *they predict a drastic change in the estimated long run ranking for the labor productivity.* Table 8 shows the correlation between the observed 1995 labor productivity ranking and the estimated ranking for the years 1995, 2025, 2055 and 2085. In the long run we obtain a negative correlation between the estimated ranking and the 1995 observed ranking. In 2055 the values are -0.14 for a model with different exogenous rates and -0.45 for a model with imitation. According to the models, in 2040, the regions of Castilla la Mancha and Extremadura will be the second and third, respectively, in terms of income per capita, while Baleares and Madrid will fall to last and before last, something that is difficult to imagine at the present time. The assumptions of this model imply that *regions in a backward technological position, the current followers, will be the future leaders*, 50 years from now. Jones (1997) also finds a similar result. He concludes that TFP convergence would result in substantial changes in the world income distribution.
- Additionally, *it is necessary to differentiate clearly between convergence in the capital/effective labor ratio and convergence in income per capita in the medium and long run.* In our estimations, it takes 40 years for the capital/effective labor ratio to reduce a 95% of the distance between the initial and the b.g.p. ranking, 32 years for a 90%. On the other hand, the income per capita needs more than 60 years to present a similar ranking to the b.g.p. ranking. This will result in a biased estimation of the speed of convergence as we will analyze below (section 6).

5. Different exogenous growth rates vs. imitation

The previous results underline the importance of the TFP both in a given year and through time as the main explanatory factor of income per capita and labor productivity convergence. A model with different exogenous growth rates or a model with imitation improve substantially the predictions of the neoclassical model with only different initial technological levels. However, using Spanish data, it is impossible to choose between both models looking at the sigma convergence values in the medium-run.

In this section, we look at the short run trying to find wich of the two models is correct. On the one hand, *we test the null hypothesis of constant growth rates of the technological factor for each region*. On the other hand, *we analyze the existence of a continuous process of technological imitation between regions*. The main distinction between an imitation model and a model with different growth rates lies in the long run predictions, convergence or stagnation against divergence, respectively. In the short and medium run, if the models have been correctly calibrated, their acceptance or rejection can only be the result of a deep, temporal and inter-regional study of the TFP growth rates.

Table 9 shows the regional TFP growth rates divided in sub-periods of 4 years.

We can observe the existence of periods of high and low growth rates clearly marked which are also reproduced in the regional patterns. We consider 1965-73 and 1985-89 as periods with higher growth rates of the technological factor, and 1973-85 and 1989-95 as periods with lower rates[20]. Additionally, the observed TFP growth rates show a clear positive relationship with the income per capita rates. Periods of high income per capita growth are not sufficiently explained by increases in the productive factors.

These variations are reflected in the results of our simulations. In the case where we take g_j as the annual compounded TFP growth rate between 1965 and 1979, we should have observed a divergence process in income per capita starting in the beginning of the eighties, instead of the nineties[21].

Therefore, *we reject the existence of a constant exogenous growth rate for the technological factor*. If we look at the short-run, we consider that a model with different exogenous rates is not the adequate model to explain the dynamics of the Spanish regions.

In what follows, we analyze the possibility of a continuous process of *technological catch-up or imitation.*

In order to test this relationship, we need to estimate the following regression:

$$\gamma_{TFPjt} - \gamma_{TFPMt} = \alpha + \phi \cdot \left(\frac{TFPjt}{TFP_{Mt}} \right) + u_t$$

[20] In this case, we face two possible cases: 1) these results are a representation of a cyclical behavior around the mean or 2) they are the proof of a non constant exogenous rate.

[21] This result is available from the authors on request.

TABLE 9. Annual compounded growth rates, TFP.

	1965-69	1969-73	1973-77	1977-81	1981-85	1985-89	1989-95
Andalucía	0.0523	0.0637	0.0289	0.0027	0.0142	0.0502	-0.0038
Aragón	0.0566	0.0527	0.0307	0.0124	0.0155	0.0640	0.0081
Asturias	0.0564	0.0574	0.0150	0.0432	-0.0001	0.0295	-0.0001
Baleares	0.0065	0.0426	0.0173	0.0187	0.0144	0.0275	-0.0125
Canarias	0.0325	0.0754	0.0163	0.0197	0.0117	0.0423	-0.0032
Cantabria	0.0420	0.0534	0.0356	0.0182	0.0131	0.0497	0.0114
Castilla la Mancha	0.0664	0.0716	0.0156	-0.0088	0.0232	0.0748	0.0079
Castilla y León	0.0480	0.0591	0.0220	0.0116	0.0175	0.0695	0.0116
Cataluña	0.0131	0.0429	0.0194	0.0133	0.0083	0.0570	0.0093
Comunidad Valenciana	0.0260	0.0609	0.0220	0.0033	0.0131	0.0580	0.0068
Extremadura	0.0439	0.0648	0.0223	0.0311	0.0120	0.0869	0.0020
Galicia	0.0417	0.0559	0.0289	0.0168	0.0145	0.0747	0.0117
Madrid	0.0153	0.0393	0.0173	0.0077	0.0047	0.0517	-0.0013
Murcia	0.0530	0.0643	0.0104	0.0055	0.0302	0.0578	-0.0015
Navarra	0.0436	0.0664	0.0312	0.0009	0.0370	0.0460	0.0116
País Vasco	0.0416	0.0495	0.0296	-0.0146	0.0219	0.0506	0.0115
Larioja	0.0237	0.0419	0.0094	0.0086	0.0348	0.0560	0.0315
Average	0.0390	0.0566	0.0219	0.0112	0.0168	0.0557	0.0059
Standard deviation	0.017	0.011	0.008	0.014	0.010	0.015	0.010

where γ_{TFPj} is the TFP growth rate of region j, and M represents the region of Madrid. A negative value for ϕ indicates the existence of a positive relationship between the technological distance follower-leader and the growth rate of the region[22]. We also estimate the previous equation introducing a quadratic term.

The estimations are presented in Table 10. The results depend on the choice of aggregation for the growth rates. We confirm the validity of this relationship, with the proper sign, for the periods 1965-69, 1969-73 and 1985-89, while we reject it for the other periods. The test F for the equality of the ϕ parameter for all the periods rejects the null hypothesis of a single continuous process of technological imitation.

From Tables 9 and 10, we also conclude that there is a positive relationship between the TFP (and the income per capita) growth rates and the existence of technological catch-up. Periods in which the catch-up relationship is significant coincide with periods of higher TFP growth rates. *However, we reject the existence of an unique stable relationship between the*

[22]The lack of a significant relationship could mean the absence of technological imitation, or that the effect of innovation on the leaders is larger than the effect of imitation on the followers.

Table 10. Technology catch-up regressions.

Model 1

	15 periods (a)	Only one period (b)	2 periods (c)	1st period (c1)	2nd period (c2)	7 periods (d)	1st period (d1)	2nd (d2)	3rd (d3)	4th (d4)	5th d(5)	6th d(6)	7th d(7)	
ϕ	**-0.0443**	**-0.0261**	**-0.0386**	**-0.0417**	**-0.0192**	**-0.0424**	**-0.0716**	**-0.0398**	-0.0114	-0.0196	-0.0187	**-0.0593**	-0.0110	Test F for the equality of the 'phi' parameter. (d1)-(d7).
(s.d.)	(0.0073)	(0.0038)	(0.0063)	(0.0058)	(0.0096)	(0.0069)	(0.0141)	(0.0126)	(0.0119)	(0.0212)	(0.0154)	(0.0201)	(0.0174)	
Constant	**0.0357**	**0.0232**	**0.0318**	**0.0366**	**0.0168**	**0.0348**	**0.0597**	**0.0389**	0.0112	0.0149	**0.0232**	**0.0406**	0.0141	
	(0.0044)	(0.0020)	(0.0037)	(0.0031)	(0.0060)	(0.0041)	(0.0076)	(0.0071)	(0.0071)	(0.0128)	(0.0094)	(0.0128)	(0.0111)	
R2	0.14	0.76	0.54	0.78	0.21	0.24	0.63	0.40	0.06	0.05	0.09	0.37	0.03	2.41(')

Model 2

	(a)	(b)	(c)	(c1)	(c2)	(d)
ϕ	**-0.1833**	**-0.0439**	**-0.1181**	**-0.0787**	-0.0488	**-0.1411**
	(0.0441)	(0.0213)	(0.0330)	(0.0318)	(0.0679)	(0.0399)
Quadratic term	**0.1066**	0.0145	**0.0638**	0.0304	0.0221	**0.0770**
	(0.0333)	(0.0172)	(0.0261)	(0.0256)	(0.0501)	(0.0307)
Constant	**0.0775**	**0.0279**	**0.0543**	**0.0465**	0.0262	**0.0640**
	(0.0137)	(0.0060)	(0.0098)	(0.0089)	(0.0221)	(0.0123)
R2	0.18	0.77	0.61	0.80	0.22	0.28

(') Non significative at 5%.

Model 1. Independent variable: TFP growth rate, region j, minus the TFP growth rate of the region of Madrid. Dependent variable: a constant term and the ratio TFP level of the region j / TFP level of Madrid.

Model 2. Quadratic term: TFP of the region j / TFP of Madrid, squared.

(a) 255 observations. For each region, the annual compounded growth rate (ACGR) for the biannual periods, and the levels of the TFP every two years starting in 1965.

(b) 17 observations. For each region, the ACGR for the period 1965-95 and the 1965 TFP levels.

(c) 34 observations. For each region, the ACGR for the periods 1965-79 and 1979-95, and the TFP levels in 1965 and 1979.

(c1) 17 observations. The ACGR for the period 1965-79 and the TFP levels in 1965.

(c2) 17 observations. The ACGR for the period 1979-95 and the TFP levels in 1979.

(d) 119 observations. The ACGR for the periods 1965-69, 1969-73, 1973-77, 1977-81, 1981-85, 1985-89 and 1989-95, and the TFP levels for the periods 1965, 1969, 1973, 1977, 1981, 1985 and 1989.

(d1)-(d7) 17 observations. The ACGR and the TFP levels for the periods displayed in (d).

distance to the leader and the growth rates of the TFP. Therefore, we cannot use the short run in order to choose between a model with imitation and a model with different exogenous rates. Both are rejected.

Although the neoclassical model with different growth rates or a model with imitation adjust better to the empirical evidence (medium-run) than a model without different technological dynamics for each region, we conclude that they present two important problems: a) the dynamic analysis of the growth rates of the total factor productivity in the short run rejects the existence of a constant growth rate or a process of imitation; and b) the models, in the long run, predict a drastic change in the regional ranking.

6. Speed of convergence

Until now, we have looked at the $\sigma-$convergence statistic. In this section, we calculate the speed of convergence for the estimated and observed data. We obtain both the value of $\beta-$convergence and the speed resulting from fixed effect panel data regressions. If there exist different exogenous rates, the $\beta-$convergence or panel data estimations are biased, see Lee et al.

(1997). Indeed, the concept of speed of convergence for the labor productivity loses its meaning derived from the neoclassical model characteristics.

The objetive of this section is to check the error when we do not assume a different role for the evolution of the TFP for each region. As we get rid of the technological factor when we calculate the capital/effective labor ratio (KLE), the estimated speed of convergence for the observed and estimated KLE series should present the same value. However, as we allow for a different g for each region, this relationship does not need to hold.

The estimated regression is:

$$\frac{1}{T}\cdot\ln\left(\frac{y_{it_0+T}}{y_{it_0}}\right) = a_i + b\cdot\ln\left(y_{it_0}\right) + u$$
$$\text{where } b = \frac{e^{-\beta T}-1}{T}$$

We follow two different procedures: considering 1) $\beta-$regression with T=30 years ($a_i = a$) and 2) fixed effect panel data regression (different a_i for each region) and periods of T=4 years.

The results are displayed in Table 11. The estimated parameters are presented for both observed and estimated series for the variables: the income per capita, the labor productivity, the capital/labor ratio and the capital/effective labor ratio.

We conclude that:

- For the model with different g, the introduction of fixed effects, as commonly shown in the literature, increases the speed of convergence for all the estimated variables except for labor productivity. For the observed series, the panel data estimation increases the speed of convergence for the income per capita and the capital /effective labor ratio, while it results in a similar speed for the labor productivity and the capital/labor ratio[23]. *This higher speed, however, implies the necessity of assuming different steady states.*
- The speed of convergence is for both observed and estimated series higher for the capital/effective labor ratio than for the labor productivity. *This would favor the idea of technology transfers between regions* and represents the type of bias exposed in Lee et al. (1997). For the observed series the speed of convergence increases from 0.0125 to 0.0774.

Table 12 presents the speed of convergence for the capital/effective labor ratio (KLE) when estimating the $\beta-$convergence regression for each region separately[24]. We can conclude the following:

[23] The difference between the speeds of convergence of the income per capita and the labor productivity obtained from panel data estimations, 4.1% and 1.25%, are due to the disparities in the regional labor participation rates.

[24] Biannual data. 16 observations per region.

TABLE 11. Speed of convergence. Observed and estimated series.

	Y/P Observado	Y/L Observado	Estimado Distinto g	Estimado Imitación	K/L Observado	Estimado Distinto g	Estimado Imitación	K/(L*PTF) Observado	Estimado Distinto g	Estimado Imitación
Barro										
b	-0.0127	-0.0186	-0.0103	-0.0134	-0.0265	-0.0153	-0.0158	-0.0116	-0.0044	-0.0037
d.t	(0.0027)	(0.0019)	(0.0012)	(0.0011)	(0.0037)	(0.0027)	(0.0047)	(0.0039)	(0.0023)	(0.0023)
speed	0.0070	0.0118	0.0054	0.0074	0.0230	0.0089	0.0093	0.0062	0.0021	0.0017
Datos de panel Efectos fijos										
b	-0.0789	-0.0272	-0.0006	-0.0370	-0.0540	-0.0465	-0.0682	-0.1274	-0.0779	-0.0971
d.t	(0.0127)	(0.0133)	(0.0049)	(0.0037)	(0.0139)	(0.0068)	(0.0046)	(0.0166)	(0.0023)	(0.0013)
speed	0.0412	0.0125	0.0002	0.0174	0.0264	0.0223	0.0346	0.0774	0.0405	0.0534

Regresión de beta-convergencia. 17 observaciones. Periodo 1965-95.
Datos de panel. Efectos fijos. 119 observaciones. 18 parámetros a estimar. Periodos de 4 años.

- The mean and median values of the speed of convergence for the observed data are lower when we estimate the speed separately than when we use the panel data regressions[25]. The estimations for each region present high standard deviation values that drive us to reject the significance of the estimated parameters for most of the regions -we cannot reject the existence of an unit root for their KLE ratio. The F-test for the equality of all b_j is accepted with a probability of 0.68.
- The mean and median for the model with different g are over 6% while with panel data methods we obtained 4%. The speeds of convergence range from a minimum of 0.032 for Extremadura to a maximum of 0.085 for Madrid. The existence of different g_j for each region not only can bias the estimation for the labor productivity, but it can also bias the estimation for the capital/effective labor ratio when estimating panel data regressions, obtaining a value that is lower than the average speed.
- The value for the mean and median in the model with imitation is similar to the one estimated through panel data regressions, 0.054. However, due to the way we have constructed the series we know that the speeds of convergence are not equal. Their values range from a minimum of 0.043 for Castilla la Mancha to a maximum of 0.076 for the region of Madrid.

Therefore, we conclude that *the analysis of the labor productivity or income per capita without explicitly considering the role of the technology factor can result in erroneous conclusions*. Also, *the introduction of a different dynamic for the technology factor in each region allows linking coherently the observed speed of convergence with a normally accepted value for the capital share.*

[25]The high speed for the region of Cantabria could be biasing the panel data estimations.

Table 12. Estimation of a different speed of convergence for each region.

	Data		Diff g		Imitation		Speed of convergence		
	b	(s.d.)	b	(s.d.)	b	(s.d.)	Data	Diff g	Imitation
Andalucía	0.0070	(0.0440)	-0.1108	(0.0010)	-0.1161	(0.0009)	-0.003	0.054	0.057
Aragón	-0.1297	(0.0865)	-0.1368	(0.0000)	-0.0973	(0.0003)	0.065	0.069	0.047
Asturias	0.0066	(0.0911)	-0.1397	(0.0002)	-0.1107	(0.0006)	-0.003	0.071	0.054
Baleares	-0.1350	(0.0404)	-0.1108	(0.0011)	-0.1250	(0.0011)	0.068	0.054	0.062
Canarias	-0.1165	(0.0508)	-0.1234	(0.0006)	-0.1224	(0.0008)	0.058	0.062	0.061
Cantabria	-0.2616	(0.1356)	-0.1381	(0.0001)	-0.1000	(0.0003)	0.161	0.070	0.048
Castilla La Mancha	-0.0292	(0.0495)	-0.0927	(0.0008)	-0.0896	(0.0006)	0.013	0.045	0.043
Castilla y León	-0.0602	(0.0540)	-0.1074	(0.0005)	-0.0956	(0.0006)	0.028	0.053	0.046
Cataluña	-0.1629	(0.0489)	-0.1269	(0.0002)	-0.1153	(0.0007)	0.086	0.064	0.057
Comunidad Valenciana	-0.1003	(0.0426)	-0.1169	(0.0008)	-0.1172	(0.0009)	0.049	0.058	0.058
Extremadura	-0.0670	(0.0575)	-0.0692	(0.0013)	-0.0912	(0.0007)	0.031	0.032	0.044
Galicia	-0.0473	(0.0593)	-0.1109	(0.0005)	-0.0978	(0.0006)	0.022	0.054	0.047
Madrid	-0.1614	(0.0651)	-0.1637	(0.0003)	-0.1475	(0.0007)	0.085	0.086	0.076
Murcia	-0.0452	(0.0655)	-0.1305	(0.0003)	-0.1142	(0.0006)	0.021	0.066	0.056
Navarra	-0.1082	(0.0920)	-0.1536	(0.0000)	-0.1113	(0.0004)	0.053	0.080	0.055
País Vasco	-0.1468	(0.0922)	-0.1407	(0.0001)	-0.1074	(0.0003)	0.075	0.072	0.053
La Rioja	-0.0809	(0.0416)	-0.1047	(0.0007)	-0.1007	(0.0007)	0.038	0.051	0.049
Mean	-0.0964		-0.1222		-0.1094		0.050	0.061	0.054
Median	-0.1003		-0.1234		-0.1107		0.049	0.062	0.054
Maximum	0.0070		-0.0692		-0.0896		0.161	0.086	0.076
Minimum	-0.2616		-0.1637		-0.1475		-0.003	0.032	0.043
F-test. The same b for all the regions.	F-text 0.81	Prob 0.68	F-text 518.11	Prob 0	F-text 324.42	Prob 0			

Note: T=2 years. 16 observations per region.

7. Conclusions

We confirm the existence of an income per capita convergence process, especially important in the sixties and seventies. The characteristics of this process, however, are not as normally expected from an standard analysis of the neoclassical model.

The decomposition of the income per capita variance underlines the crucial importance of TFP convergence in explaining income per capita convergence. Our analysis reveals that not only different steady states should be assumed in future analysis, but also their dynamic evolution. This has important consequences for the fixed effect panel data regressions. The estimated speed of convergence is biased. The comparison of the panel data regressions for the estimated and observed series yields the conclusion that not taking care of the possible differences in the regional technology dynamic can result in biased estimations of the speed of convergence.

The empirical evidence refutes the neoclassical model with the same growth rates of the technological factor for all the regions. Two facts are crucial for this result: a) the reduction in the total factor productivity differences and its importance in the evolution of income per capita differences;

and b) the absence of correlation between the income per capita and the capital/labor ratio since 1985.

We also conclude that a model with different exogenous rates of with imitation can explain the observed dynamics. Our results imply a reduction in the importance of the neoclassical dynamic transition for the Spanish convergence process underlying the differences between steady states, and the factors that affect their temporal evolution, as the main determinants of the income per capita differences between the Spanish regions.

Although the neoclassical model with different growth rates or a model with imitation adjust better to the empirical evidence than a model without different technological dynamics for each region, they present two important problems: a) the dynamic analysis of the growth rates of the total factor productivity rejects the existence of a constant growth rate or a process of imitation; and b) the models, in the long run, predict a drastic change in the regional ranking.

References

[1] Arévalo, P. (2002): "Transitional Dynamic and Economic Growth in Spain, 1959-98 ", MIMEO.

[2] Barro, R. and Sala-i-Martín, X. (1991): "Convergence across States and Regions," *Brookings Papers on Economic Activity*, n^o 1, 107-182.

[3] De la Fuente, A. (1998): "Algunas técnicas para el análisis de la convergencia con una aplicación a las regiones españolas", *Documento de Trabajo de la Dirección General de Análisis y Programación Presupuestaria, ministerio de Economía y Hacienda*, D-98007.

[4] De la Fuente, A. (1997): "On the Sources of Convergence: A Close Look at the Spanish Regions", Studies on the Spanish Economy, FEDEA.

[5] Escribá Pérez, F.J. and Murgui García, M.J. (1998): "La productividad total de los factores entre sectores y regiones en la Economía Española (1980-1993)", *Documento de Trabajo de la Dirección General de Análisis y Programación Presupuestaria, Ministerio de Economía y Hacienda*, D-98005.

[6] Fundación BBVA (various years), "Renta Nacional de España y su Distribución Provincial", Bilbao.

[7] Hall, Robert E. and Jones, Charles I. (1999): "Why do some countries produce so much more output per worker than others?" *The Quarterly Journal of Economics*, February 1999.

[8] Instituto Nacional de Estadística, *www.ine.es*.

[9] Islam, N. (1995): "Growth empirics: a panel data approach", *The Quaterly Journal of Economics*, 1995.

[10] Jones, C. (1997): "Convergence revisited", Stanford University, working paper.

[11] Lee, K., Pesaran, M.H. and Smith, R. (1997): "Growth and convergence in a multi-country empirical stochastic Solow model", *Journal of Applied Econometrics*, Vol. 12, 357-392.

[12] Mankiw, N. G., Romer D. and Weil, D. N. (1992): "A Contribution to the Empirics of Economic Growth", *Quarterly Journal of Economics*, Vol. 107 (2), Mayo 1992.

[13] Mas, M., Pérez, J. and Uriel, E. (1998): "El stock de capital en España y sus comunidades autónomas", *Fundación BBV*, Madrid, vols. I, II, III y IV.

[14] Maudos, J., Pastor, J. M. and Serrano, L. (2000): "Crecimiento de la productividad y su descomposición en progreso técnico y cambio de eficiencia: una aplicación sectorial y regional en España (1964-93)", *Investigaciones Económicas*, vol. 24(1), 177-205.

Table 13. Correlations between the levels of the variables.

Aggregate Sector

Correlations Levels

Income per Capita	Labor Share			Real Wage			K/L Ratio		
	1965	1975	1995	1965	1975	1995	1965	1975	1995
1965	-0.48	-0.23	0.17	0.90	0.89	0.87	0.59	0.66	-0.20
1975	-0.54	-0.33	0.10	0.85	0.84	0.82	0.55	0.67	-0.17
1995	-0.51	-0.28	-0.11	0.72	0.72	0.78	0.29	0.43	-0.27

Income per Capita	K/Y Ratio			Labor Productivity			TFP Levels		
	1965	1975	1995	1965	1975	1995	1965	1975	1995
1965	-0.55	-0.65	-0.81	0.97	0.94	0.87	0.91	0.89	0.84
1975	-0.56	-0.63	-0.78	0.93	0.92	0.84	0.88	0.86	0.78
1995	-0.68	-0.71	-0.87	0.80	0.77	0.86	0.84	0.78	0.83

Income per Capita	K/(L*TFP) Ratio			Rate of Return to Capital			Income per Capita		
	1965	1975	1995	1965	1975	1995	1965	1975	1995
1965	-0.18	-0.15	-0.65	0.58	0.50	0.62	1.00	0.98	0.87
1975	-0.20	-0.12	-0.62	0.59	0.55	0.63	0.98	1.00	0.90
1995	-0.41	-0.30	-0.72	0.78	0.70	0.81	0.87	0.90	1.00

Appendix A. Correlations between series

Tables 13 and 14 present the correlations between the variables and the income per capita. The regional levels in 1965, 1975 and 1995, and the annual compounded growth rates for the periods 1965-75, 1975-95 and 1965-95 of all the variables are compared against the income per capita levels in 1965, 1975 and 1995, and the income per capita annual compounded growth rates in the periods 1965-75, 1975-95 and 1965-95.

A.0.1. *Series in levels.*

- Table 13 shows high correlation values between the income per capita and the variables: the labor productivity, the real wage, the capital productivity (Y/K) and the total factor productivity.
- The values of the correlations decrease during the sample period for the labor productivity, the real wage and the TFP. They increase, in absolute value, for the inverse of the capital productivity.
- There are high positive correlations, 0.59 and 0.67, between the capital/labor ratio and the income per capita for the years 1965 and 1975, respectively, while the correlation is negative -0.269 in the year 1995. The differences in the intensity of the capital factor over the labor factor do not influence in the observed differences in income per capita in the year 1995.
- Given the high correlation between the TFP and the income per capita, the capital/effective labor ratio presents in 1995 a high negative correlation, -0.849. Poorer regions present higher capital/effective labor ratios than richer regions.

Table 14. Correlations. Variables in growth rates.

Aggregate sector

Correlations Growth rates

Income per Capita		Labor Share 1965-75	Labor Share 1975-95	Labor Share 1965-95	Real Wage 1965-75	Real Wage 1975-95	Real Wage 1965-95	K/L Ratio 1965-75	K/L Ratio 1975-95	K/L Ratio 1965-95
Levels	1965	0.47	0.36	0.60	-0.40	-0.65	-0.75	-0.08	-0.85	-0.75
	1975	0.41	0.41	0.61	-0.36	-0.65	-0.72	0.02	-0.85	-0.71
	1995	0.42	0.20	0.43	-0.31	-0.43	-0.52	0.14	-0.67	-0.49
Growth rates	1965-75	-0.48	-0.30	-0.56	0.44	0.52	0.65	0.24	0.77	0.76
	1975-95	-0.09	-0.59	-0.56	0.15	0.59	0.58	0.26	0.63	0.67
	1965-95	-0.30	-0.56	-0.66	0.34	0.66	0.73	0.29	0.82	0.84

Income per Capita		K/Y Ratio 1965-75	K/Y Ratio 1975-95	K/Y Ratio 1965-95	Labor Productivity 1965-75	Labor Productivity 1975-95	Labor Productivity 1965-95	TFP Levels 1965-75	TFP Levels 1975-95	TFP Levels 1965-95
Levels	1965	0.27	-0.65	-0.10	-0.69	-0.75	-0.88	-0.64	-0.61	-0.81
	1975	0.33	-0.62	-0.03	-0.61	-0.77	-0.87	-0.65	-0.66	-0.84
	1995	0.44	-0.68	0.04	-0.59	-0.50	-0.63	-0.71	-0.36	-0.68
Growth rates	1965-75	-0.13	0.72	0.27	0.74	0.61	0.78	0.53	0.38	0.60
	1975-95	0.16	0.05	0.17	0.19	0.77	0.72	0.02	0.79	0.56
	1965-95	0.03	0.41	0.24	0.51	0.84	0.89	0.30	0.73	0.69

Income per Capita		K/(L*TFP) Ratio 1965-75	K/(L*TFP) Ratio 1975-95	K/(L*TFP) Ratio 1965-95	Rate of Return to Capital 1965-75	Rate of Return to Capital 1975-95	Rate of Return to Capital 1965-95	Income per Capita 1965-75	Income per Capita 1975-95	Income per Capita 1965-95
Levels	1965	0.22	-0.82	-0.35	-0.46	0.17	-0.36	-0.87	-0.47	-0.76
	1975	0.30	-0.80	-0.27	-0.42	0.12	-0.38	-0.79	-0.46	-0.72
	1995	0.41	-0.71	-0.11	-0.56	0.20	-0.39	-0.69	-0.03	-0.39
Growth rates	1965-75	-0.04	0.83	0.50	0.48	-0.21	0.30	1.00	0.40	0.79
	1975-95	0.16	0.40	0.41	-0.19	0.21	0.15	0.40	1.00	0.87
	1965-95	0.08	0.71	0.53	0.13	0.03	0.27	0.79	0.87	1.00

- There is a positive correlation between the rate of return to capital and the income per capita. The values are 0.58, 0.54 and 0.80 for 1965, 1975 and 1995, respectively.
- In the year 1965, the labor share is negative correlated with the income per capita.

A.0.2. *Growth rates vs. growth rates:*

- The correlation between the income per capita growth rates for the periods 1965-75 and 1975-95 is 0.40.
- There is a high positive correlation between the income per capita and the labor productivity growth rates, 0.73 and 0.77, for the periods 1965-75 and 1975-95, respectively. The correlation with the real wage is slightly lower, 0.44 and 0.58. In the other hand, for the inverse of the capital productivity, we obtain values that are close to cero.
- The correlation between the income per capita and the capital/labor ratio growth rates is 0.24 and 0.62, for the periods 1965-75 and 1975-95, respectively. This underlines the low importance of the capital/labor ratio evolution for the explanation of the income per capita variation in the period 1965-75.

A.0.3. *Growth rates vs. levels:*

- The correlation between the income per capita growth rates in the periods 1965-75 and 1965-95 and the level of the income per capita in 1965 is -0.87 and -0.76, respectively. The correlation decreases to -0.46 for the period 1975-95 and the level in 1975. Poorer regions have grown more, a process that is more important in the first part of the sample.
- Other variables with a negative correlation between their growth rates and the levels of the income per capita are: the labor productivity, the real wage and the TFP for both periods 1965-75 and 1975-95; the capital labor ratio, the capital/output ratio and the capital/effective labor ratio for the second period, 1975-95; and the rate of return to capital for the first period, 1965-75.
- Lastly, the labor share growth rate shows a positive correlation with the levels of income per capita.

Appendix B. Design of the estimated series

After obtaining the series KLE ($\hat{k}$) in the simulation, the rest of the series are calculated using the following equations:

$$TFP_t = TFP_{1965} \cdot (1+g)^t$$
$$k_t = TFP_t \cdot \hat{k}_t$$
$$\hat{y}_t = \frac{Y_t}{L_t \cdot A_t} = \left((1-\alpha) + \alpha \cdot \hat{k}_t^{\rho}\right)^{\frac{1}{\rho}}$$
$$y_t = TFP_t \cdot \hat{y}_t$$
$$\frac{K_t}{Y_t} = \frac{\hat{k}_t}{\hat{y}_t}$$
$$r_t = \alpha \cdot \hat{k}_t^{\rho-1} \cdot \left((1-\alpha) + \alpha \cdot \hat{k}_t^{\rho}\right)^{\frac{1}{\rho}-1} - \delta$$
$$w_t = TFP_t \cdot (1-\alpha) \cdot \left((1-\alpha) + \alpha \cdot \hat{k}_t^{\rho}\right)^{\frac{1}{\rho}-1}$$
$$LS_t = \frac{(1-\alpha)}{(1-\alpha) + \alpha \cdot \hat{k}_t^{\rho}}$$

where we use g or g_j depending on the model.

Appendix C. Correlations between the variables and the labor productivity

The correlations between the variables and the levels of the labor productivity are presented in the Figure 3.

The observed correlation, in 1995, between the capital/labor ratio and the labor productivity, close to 0, is only explained by a model in which the technological performance is different among regions, and always as a medium run result.

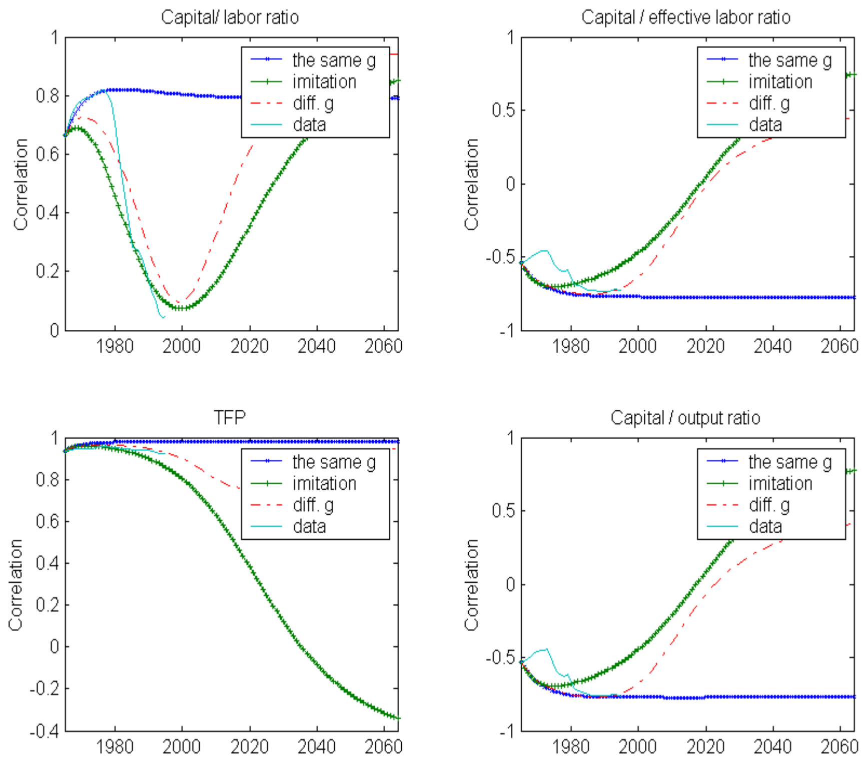

FIGURE 3. Correlations between the variables and the labor productivity.

Appendix D. Regional simulations

Our results are based on the measurement of the σ-convergence value. This, however, can be hiding different regional characteristics. This Appendix presents for each region the observed and estimated series for a model with different g and ρ in the following variables: the capital/effective labor ratio, the effective labor productivity, the rate of return to capital and the capital/output ratio.

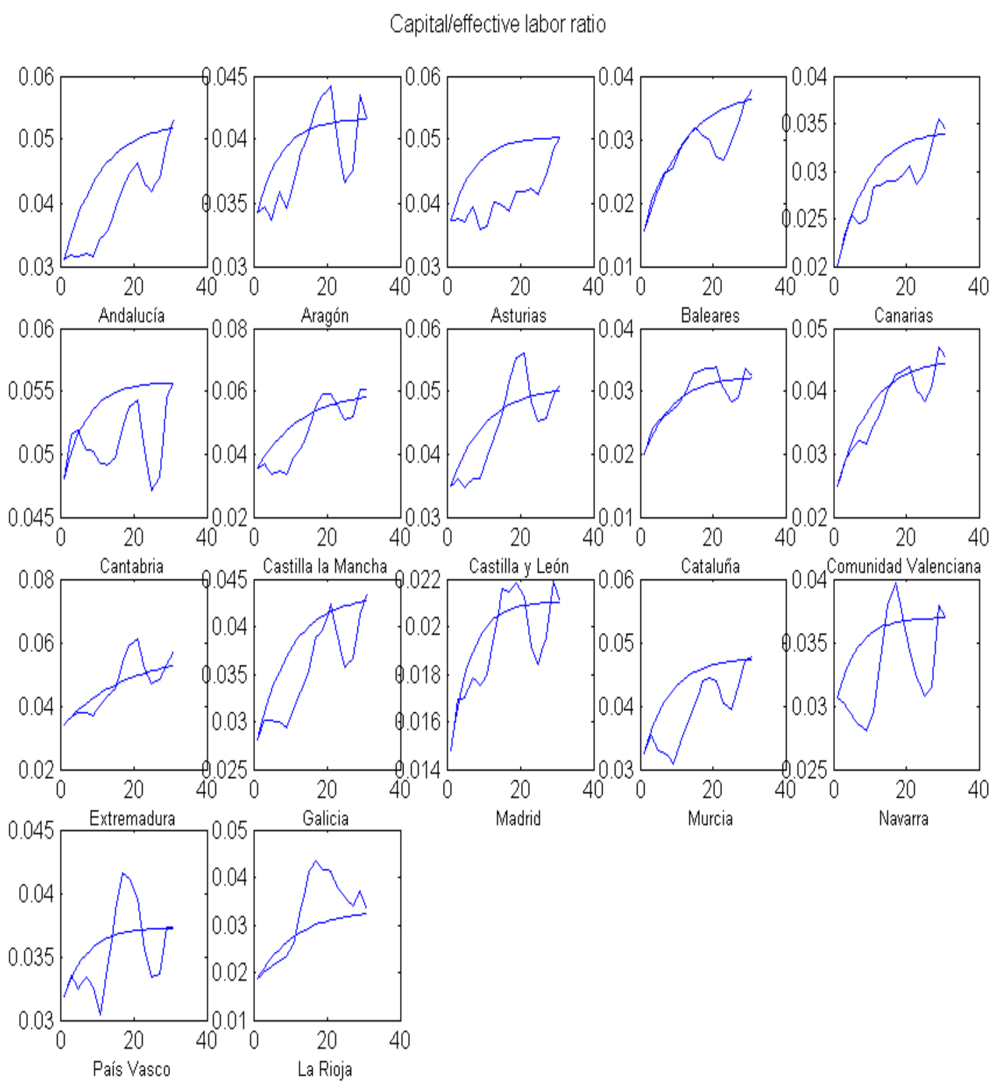
Capital/effective labor ratio
Andalucía
Aragón
Asturias
Baleares
Canarias
Cantabria
Castilla la Mancha
Castilla y León
Cataluña
Comunidad Valenciana
Extremadura
Galicia
Madrid
Murcia
Navarra
País Vasco
La Rioja

FIGURE 4

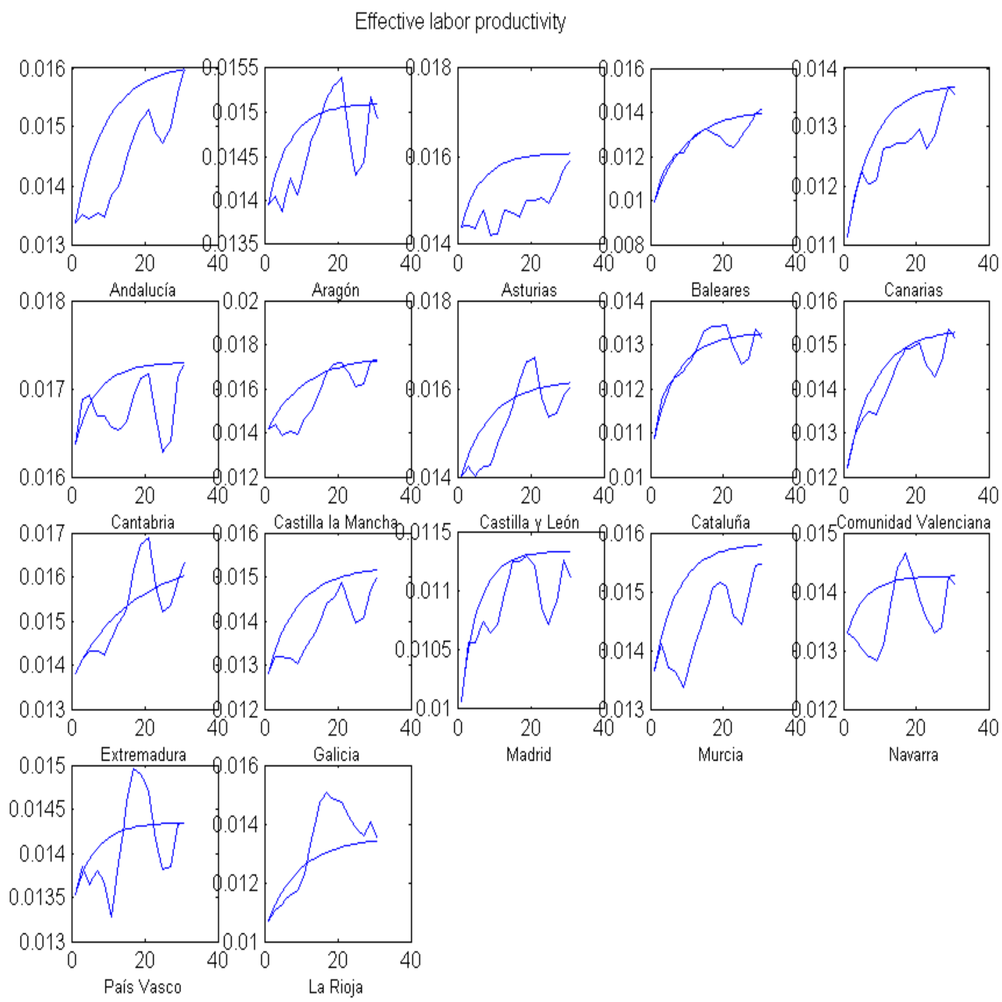
Effective labor productivity
Andalucía
Aragón
Asturias
Baleares
Canarias
Cantabria
Castilla la Mancha
Castilla y León
Cataluña
Comunidad Valenciana
Extremadura
Galicia
Madrid
Murcia
Navarra
País Vasco
La Rioja

Figure 5

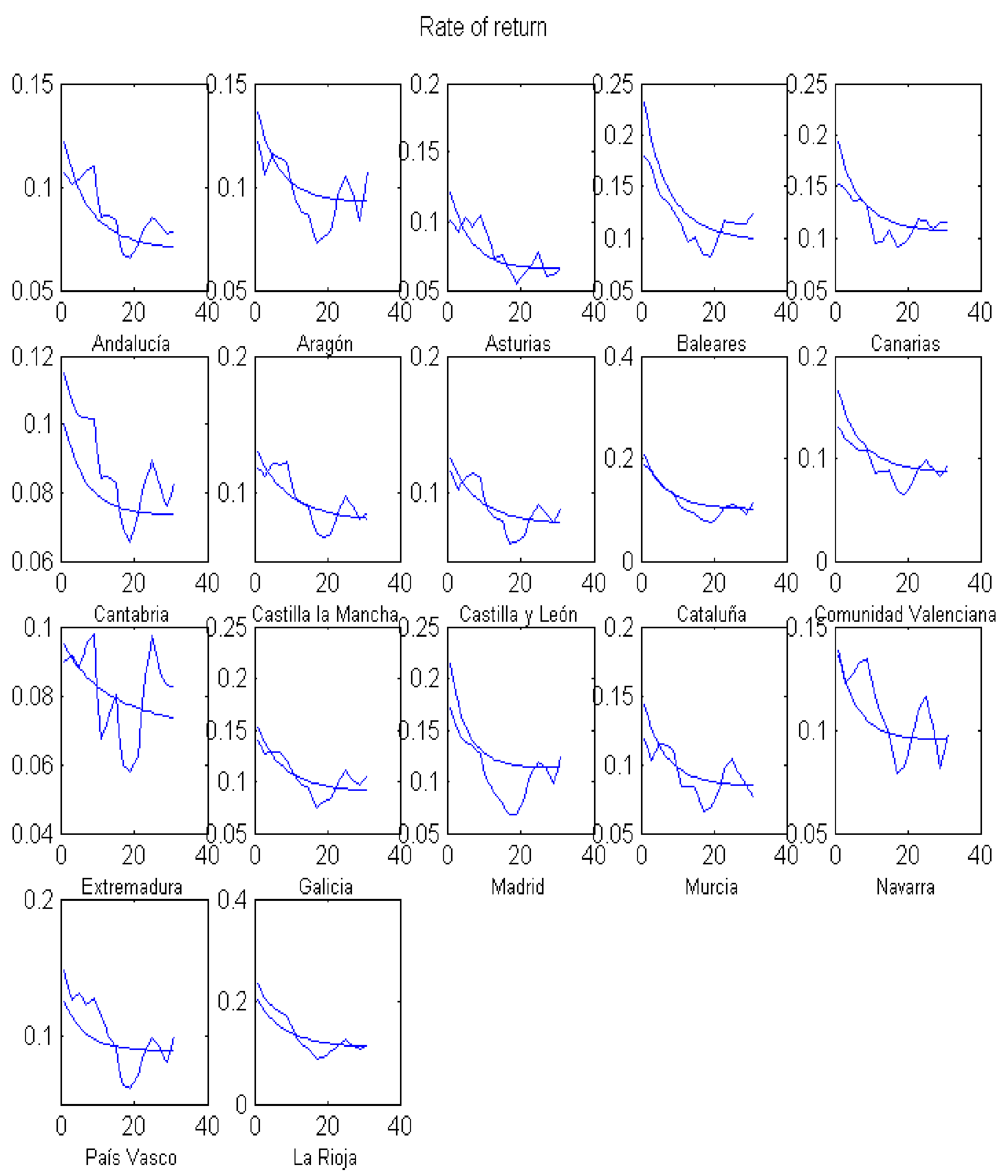
Rate of return
Andalucía
Aragón
Asturias
Baleares
Canarias
Cantabria
Castilla la Mancha
Castilla y León
Cataluña
Comunidad Valenciana
Extremadura
Galicia
Madrid
Murcia
Navarra
País Vasco
La Rioja

Figure 6

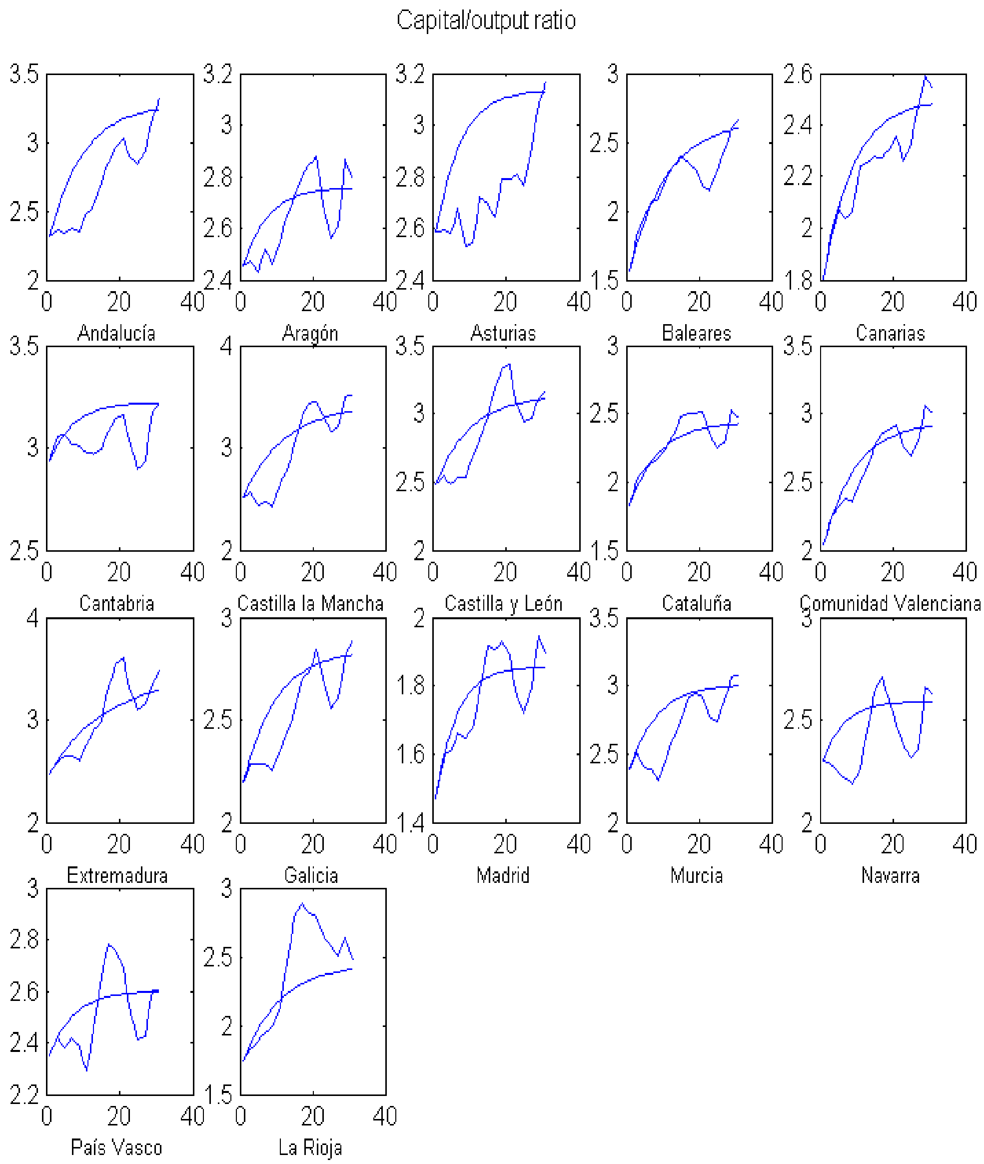
Capital/output ratio
Andalucía
Aragón
Asturias
Baleares
Canarias
Cantabria
Castilla la Mancha
Castilla y León
Cataluña
Comunidad Valenciana
Extremadura
Galicia
Madrid
Murcia
Navarra
País Vasco
La Rioja

FIGURE 7