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Public Capital, Growth and Convergence in Spain. A Counterfactual Density Estimation Approach*†

Leone Leonida‡, Daniel Montolio§

Abstract

The purpose of this paper is to study the dynamics of growth and convergence in Spain for the period 1965-1995. We analyse the evolution of the per capita income distribution across Spanish provinces and estimate the effects on this evolution of factors such as private, human and public capital, and an industrialisation index. We show that after a period of absolute convergence over the 60's and early 70's, the provinces polarised (club convergence) during the 80's. This polarisation process preceded a period of divergence among clubs, which began to appear during the 90's. Moreover, by estimating counterfactual densities, we show that private capital accumulation and education at graduate level have an effect on the growth process of rich provinces and can account for a relevant fraction of the actual dispersion and polarisation of incomes. In addition, we found that public capital has reduced inequalities, especially in recent years, through redistribution of incomes rather than by increasing productivity. Finally, industrialisation explains a smaller fraction of such processes once estimates are controlled for all the other growth determinants.

JEL: C14, O40, O41

Key words: Growth, Convergence, Public Capital, Counterfactual Densities.

Resumen: Este trabajo estudia las dinámicas de crecimiento y convergencia en España durante el periodo 1965-1995. Analizamos la evolución de la distribución de la renta per cápita entre las provincias españolas y estimamos el efecto, en dicha evolución, de factores como el capital privado, humano y público además del efecto de un *índice* de industrialización. Se muestra como después de un periodo de convergencia absoluta en los años 60 y principios de los 70, las provincias se polarizaron (*club convergence*) durante los 80. Dicha polarización precede un periodo de divergencia entre los clubes de renta que ha aparecido durante la década de los 90. Además, estimando densidades contrafactuales mostramos que el capital privado y la educación superior tienen un efecto en los procesos de crecimiento de las provincias más ricas y provocan una parte importante de la actual polarización de la renta. El capital público ha reducido desigualdades, especialmente en los últimos años, a través de la redistribución de la renta más que por incrementos de la productividad de las provincias. Finalmente, los procesos de industrialización explican una fracción menor de dichos procesos una vez se han controlado las estimaciones por el resto de variables.

JEL: C14, O40, O41

Key words: Crecimiento, Convergencia, Capital Público, Densidades Contrafactuales.

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1 Introduction

The regression approach is still the framework of reference for economists who aim to analyse the empirical determinants of economic growth and convergence processes across economies. However, recently, a completely different approach has emerged, focusing on the analysis of the *entire* distribution of per capita income across a sample of economies rather than only on its mean and variance (Quah, 1997).

From the perspective of the debate on growth determinants, this new approach allows to relax the hypothesis, implicit in a "growth regression" framework, that the growth process is common to *all* economies. If the latter is not the case, an analysis which examines the overall distribution of incomes provides us with more information than the analysis of the conditional mean.

Density estimation has been extensively applied and interesting new stylized facts have been found (Quah, 1997; Paap and van Dijk, 1998; Bianchi, 1999; Lamo, 2000). However, this approach needs some refinements especially when applied to the study of growth and convergence issues (Quah, 1996c). We are convinced that its main shortcomings are due to the necessity of estimating distributions by means of a complete non-parametric technique, since it is free from any theoretical constraint, this estimation framework is particularly appealing to the study of the dynamics of a set of economies with respect to their growth and convergence processes; however, such lack of economic structure makes the econometric results difficult to interpret in the light of economic theory: the strength of the non-parametric technique in uncovering *if* a sample of economies grows and converges represents its primary weakness when the researcher wants to address *why* one observes growth, convergence or divergence. In fact, it is difficult to assess within a completely non-parametric setup questions like "are private, human and public capital stocks sources of economic growth?" or "do these variables promote convergence across economies?"

Thus, the aim of the present study is twofold. First, we study the dynamics of the per capita income distribution across the Spanish provinces over the period 1965-1995 using the same methodology as Lamo (2000), i.e. non-parametric techniques. Lamo (2000) focuses on the empirical estimation of stochastic kernels to estimate the degree of persistence in income disparities across the Spanish provinces. We address this issue again because we believe that the time structure of the transitions she uses, transitions occurring every year in the distribution, tends to hide interesting features of long run growth processes. We show that if the time span is allowed to be longer than in Lamo (2000), as for example in Quah (1997), medium run changes in the composition of "middle class" provinces define the long run processes of growth and convergence in Spain, *even if the sample displays persistence in income disparities in the short run*. We show that, after a period of absolute convergence over the 60s and early 70s, the provinces polarised (club convergence) during the 80s. This polarisation process preceded a period of divergence among clubs which began to appear during the 90s.

Second, we refer to the evolution of the actual distribution rather than its steady state characteristics in order to define an estimation framework linking economic theory with the non-parametric framework. Using a conditioning scheme directly derived from economic theory, we remove the effects of some "economic fundamentals" from the evolution of the per capita income distribution obtaining, "counterfactual distributions" (Di Nardo, Fortin and Lemieux, 1996). The difference between the *actual* and the *counterfactual* distribution is a measure of the effects of the "washed-up" variable on growth dynamics. Our effort results in a semi-parametric approach which yields information on the effects of variables such as private, human and public capital and an industrialisation index on growth and convergence processes observed in Spain over the last decades. Hence, the resulting framework leads to an empirical analysis that is closer (and with comparable results), to a more traditional "growth regression" with regard to the estimate of the steady state only. A number of interesting new stylized facts emerge from our analysis. We show that private capital accumulation and education at graduate level can explain the growth process of rich provinces and a relevant fraction of the dispersion and polarisation of incomes, while public capital has reduced income inequalities, especially in recent years, through redistribution of incomes, rather than by increasing productivity. Finally, industrialisation, once estimates are controlled for all the other determinants, accounts for only a smaller fraction of such processes.

The paper is organised as follows. Section 2 briefly reviews the theoretical and empirical debate on growth and convergence, with special reference to the Spanish literature. Section 3 describes the methodology we employ. Section 4 presents the variables and data used in the empirical estimations. Section 5 reports our empirical results on convergence across Spanish provinces. Section 6 presents our results with regard to counterfactual densities. Finally, section 7 sums up our conclusions.

2 Growth and Convergence in Spain

Classical models à la Solow (1956) and their predictions on convergence have been subjected to many kinds of empirical tests and further theoretical developments (see for instance, Barro and Sala-i-Martin, 1996 or de la Fuente, 1997 for a summary). The empirical evidence argues against "absolute convergence" if such a hypothesis is tested across economies with different levels of development (Baumol, 1986). This finding led to the development of the "conditional convergence hypothesis" by authors such as Barro and Sala-i-Martin (1991) and Mankiw, Romer and Weil (1992), which provides the main theoretical framework for introducing different variables as growth determinants. Conditional convergence provides a framework that captures the existence of different steady states when testing for convergence; in other words, the idea is to control for structural variables that determine the steady states towards which the economies are converging. Using this framework, growth models have been "augmented" to account for variables such as human and public capital as growth determinants.

Growth and convergence issues in Spain have been mainly studied using such "convergence equations", and focussing mainly on regional economies. Pioneering works include Raymond and García-Greciano (1994), who investigated growth and convergence at the regional level, and Dolado, González-Páramo and Roldán (1994), who analysed the provincial case.[1] Recently, Lamo (2000) has applied a non-parametric framework to the Spanish provinces. She studies long run tendencies in provincial economies by projecting their realised growth tendencies, and by estimating a proxy of the steady state distribution. She estimates stochastic kernels on the basis of one-year transitions, and concludes that persistence of income disparities is the main feature of the sample, which is robust to migration processes. Her results hold, in our opinion, because she analyses transitions between t and $t+1$ only; given the persistence that per capita income usually shows, this seems a choice that may hide interesting features of long run growth processes.

In line with the conditional convergence approach, different variables have been introduced into growth regressions to check whether they help to predict Spanish growth rates. For instance, Gorostiaga (1999) estimates a growth model with human and public capital using panel data with instrumental variables for the Spanish regions over the period 1961-1991. The conditional convergence hypothesis of heterogeneity of steady states is accounted for by means of fixed regional effects. She finds a convergence rate higher than the usual 2% (18%), and robust to the introduction of human and public capital into the estimation. Moreover, introducing human capital improves the estimates of the convergence equation indicating the possibility that this variable plays, on average, an important role in growth and convergence processes in Spain. Results for public capital as a growth determinant are less optimistic.

Recently, de la Fuente (2002) has pointed out the adequacy of estimating more disaggregated growth models (i.e. including more potential growth determinants) for a better understanding of observed growth processes. Even if the effects of these growth determinants on growth rates are significant or not in the classical approach, an analysis of their effects on the per capita income distribution across Spanish provinces is needed, since their average effect may not hold for all the quantiles of the distribution. For example, the positive effect that private capital has, on *average,* on growth rates may be the composition of a strong positive effect on only *some* provinces and an effect close to zero on others. The analysis of the income distribution would shed light on which part of the distribution benefits from capital accumulation. Moreover, the controversial effects of public capital on growth and convergence found, among others, by Gorostiaga (1999) or González-Páramo and Martínez (2002) do not mean that public spending has no effect on the *distribution* of incomes: if governments use public spending to redistribute income, then the positive effect on poorer economies may be offset, on average, by taxation of richer areas. This could be the reason why

[1] These studies were followed by other regional studies such as de la Fuente (1994), García-Greciano et al. (1995), Mas et al. (1994, 1995), Cuadrado et al. (1999) or Salas (1999). Using different specifications and econometric tools convergence has been a common result in these works.

the effect of public spending on the mean of growth rates is usually negligible (or even negative); in any case, both effects should be highlighted *via* the analysis of the overall distribution of incomes, as in the present study.

3 Methodology

This section presents both the methodology that we use to study the evolution of the distribution of incomes, and the technique that allows us to estimate the effects of a vector of "potential" growth deteminants on the income distribution.

Let x_{it} be the relative per capita income of the i_{th} province at time t, where $i = 1, ..., N$ and $t = t_0, ..., T$, and y_{it} a set of J characteristics that economic theory suggests influence x_{it}. Let $f_t(x_i)$ be the per capita income distribution and $l_t(y_{ji})$ the distribution of j_{th} characteristic, both taken at time t. Our aims are to describe the evolution of the per capita income distribution $f_t(x_i)$ through t, and to show the effect of $l_t(y_{ji})$ on $f_t(x_i)$ across time, holding constant all other $J-1$ growth determinants.

3.1 A Direct Analysis for Growth and Convergence

Our first step consists in estimating T densities, $f_t(x_i)$ $\forall t \in 1965, ..., 1995$ independently. We adopt a completely non-parametric density estimation approach; the only assumption we need is that $f_t(x_i)$ exists and it is sufficiently smoothed (Silverman, 1986). Define a kernel function as:

$$\int_{-\infty}^{\infty} K(x)dx = 1. \tag{1}$$

Given t, a broad class of density estimators may be defined as:

$$\hat{f}_{i,h}(x) = \frac{1}{Nh}\sum_{i=1}^{N} K\left(\frac{x - x_i}{h}\right), \tag{2}$$

where N is the total number of observations in the sample, and h is the bandwidth (the smoothing parameter); $K(\cdot)$ refers to a kernel and x_i is per capita income of the i_{th} observation of the sample.

Alternative kernel functions may be applied to the sample; each of them has different advantages and disadvantages (especially in terms of efficiency and smoothing power). We make use of the gaussian kernel, that is, the height of the standard normal distribution evaluated at $x - x_i$, given a bandwidth h. The choice is due, essentially, to its property of monotonicity of features, peaks and valleys, with respect to changes in the bandwidth magnitude; this property is particularly useful when comparing distributions over time (Silverman, 1981).

The bandwidth choice (h) is the crucial issue in the effective estimation of the density functions. In general, the bigger the bandwidth, the more smoothed the estimated densities; we use the Sheather and Jones (1991) smoothing parameter; however, we perform a number of robustness exercises, and show that results do not substantially change with different smoothing parameters.

Note that the estimates are performed independently $\forall t$; for this reason, distributions relative to different years have a different "optimal" bandwidth. Unfortunately, it is not possible to compare distributions estimated using different smoothing parameters: "when it is desired to compare several density estimates, meaningful comparison (of densities with comparable "features") can only be done when the same amount of smoothing is done for each curve" (Marron and Schmitz, 1992). Given that the data used have the same scale and the same cross-section dimension, Marron and Schmitz (1992) suggest the application of the average amount of optimal smoothing to each estimate.

3.2 Weighted Kernel Density Estimation and Counterfactual Densities

To analyse the effects of J conditioning variables on $f_t(x_i)$, fix t again, and define the density of x_i as:

$$f(x_i) = \int g(x_i \mid y_i) l(y_i) dy_i, \tag{3}$$

where $g(\cdot)$ is the conditional density of x_i, given a set of characteristics y_i and their joint distribution $l(y_i)$.

Suppose there exists a qualitative variable $\alpha \in y_i$, assuming value 1 if this characteristic is present and 0 otherwise (for instance, high/low private capital stock, or belonging to a particular cluster in the income distribution). We can define the (conditional) density representing the distribution of the variable x_i in the sub-samples for which the α factor is absent and the density where the factor α is present as:

$$f(x_i \mid \alpha = 0) = \int g(x_i \mid y_i, \alpha = 0) l(y_i, \alpha = 0) dy_i \tag{4}$$

and,

$$f(x_i \mid \alpha = 1) = \int g(x_i \mid y_i, \alpha = 1) l(y_i, \alpha = 1) dy_i \tag{5}$$

respectively.

To highlight the effect of the qualitative variable α on the whole distribution, we should estimate the distribution that would prevail if *all* observations had/did not have the characteristic represented by α. Why not compare these distributions with each other as an effect of the presence of α? Densities in (4) and (5) cannot be compared with each other, nor with density in (3); it is true that they are constructed by using the presence of α as discriminant; however, the difference between these distributions cannot be imputed to α only: all the remaining $J-1$ variables must be kept constant.

Johnston and Di Nardo (1997) suggest that we should estimate

$$f^{\alpha}(x_i) = \int g(x_i \mid y_i, \alpha = 0) l(y_i) dy_i, \tag{6}$$

which is exactly the distribution that would prevail at time t if all provinces did not possess the factor α. The application of Bayes' law

$$l(y_i) = \frac{l(y_i, \alpha = 0) prob(\alpha = 0)}{prob(\alpha = 0 \mid y_i)}, \tag{7}$$

and substitution of this expression in (6), yields

$$f^{\alpha}(x_i) = \int \theta_i g(x_i \mid y_i, \alpha = 0) l(y_i, \alpha = 0) dy_i, \tag{8}$$

$$f^{\alpha}(x_i) = \theta_i f(x_i \mid \alpha = 0), \tag{9}$$

where

$$\theta_i = \frac{prob(\alpha = 0)}{prob(\alpha = 0 \mid y_i)}. \tag{10}$$

Equation (9) proves that, to obtain the counterfactual density $f^{\alpha}(x_i)$ in (6), we need a measure of θ_i and the density relative to the sub-samples for which $\alpha = 0$. Therefore, three issues must be addressed: the meaning of parameters θ_i, and how to estimate and use them in a non-parametric density estimation approach.

What is θ_i? The answer is closely related to the construction of the sub-sample in (4) and (5), and to the meaning of Bayes' law in (7). It should be remembered that the densities relative to the two sub-samples cannot be directly compared with each other, nor with the distribution relative to the overall sample. The reason for this is that these sub-samples are different in construction*, but we cannot be sure that the presence of α represents the only difference among these three samples.*

This can be made clear by rearranging equation (7) as follows:

$$\frac{l(y_i)}{l(y_i \mid \alpha = 0)} = \frac{prob(\alpha = 0)}{prob(\alpha = 0 \mid y_i)}. \tag{11}$$

The ratio between the two densities in equation (11) is different to unity unless α is independent from y_i. In a growth framework this would hardly be the case: we want to hold all variables constant *apart from* α. For example, suppose $\alpha = 0$ represents "having a low private capital stock". However, being an "$\alpha = 0$" observation may mean having other different features; for instance, it may mean having a low level of human capital. If this is the case, in the "$\alpha = 0$" sub-sample, there are many observations with low human capital; such observations are overrepresented, and observations with a high level of human capital are underrepresented.

For this reason, differences in per capita income distribution across sub-samples are actually due both to α and to the different distribution of human capital ($l(y_i \mid \alpha = 0)$) with respect to the overall sample ($l(y_i)$). To estimate the effect of α only, we must correct the estimates for this second effect, the intention being to re-weight the sub-samples by giving more weight to underrepresented and less weight to overrepresented observations.

The estimated θ_i has exactly this function: it is a re-weighting vector. Suppose that α is present in 50% of the observations: $prob(\alpha = 0) = 0.5$. Following our example, in the sub-samples constructed from $\alpha = 0$ there are many observations having a low level of human capital: $prob(\alpha = 0 \mid y_i)$ is then *greater* than 0.5 for these observations. Equation (10) shows θ_i assigns them a score *smaller* than 1. In the same sub-sample, observations with high human capital have $prob(\alpha = 0 \mid y_i)$ *smaller* than 0.5: θ_i assigns to these observations a score *greater* than 1. In short, by applying θ_i all densities are made directly comparable, and the difference would be due to α only, not to the other $J - 1$ variables.

Estimates of θ_i, $\hat{\theta}_i$, may be obtained noting that in equation (10) the numerator ($prob(\alpha = 0)$) indicates the proportion of observations not having the factor α; the denominator ($prob(\alpha = 0 \mid y_i)$) may be obtained by applying a probit model,[2] defining the *conditional* probability of having/not having the factor α as a function of a vector of the other $J - 1$ characteristics. Having $\hat{\theta}_i$, and applying

$$\hat{f}_{i,h}(x_i) = \frac{1}{Nh} \sum_{i=1}^{N} \hat{\theta}_i K\left(\frac{x - x_i}{h}\right), \tag{12}$$

gives an estimate of (6).

The distance between the actual and the counterfactual densities, obtained by re-weighting the sub-sample where $\alpha = 0$, measures the *actual* effect of α on the income distribution (Di Nardo, Fortin and Lemieux, 1996). A similar measure would be obtained by re-weighting the samples for which $\alpha = 1$; in this case, weights would be $\hat{\omega}_i = 1 - \hat{\theta}_i$.

[2]Using the full vector of independent variables we estimate a probit of the form:

$$prob\,(K) = \phi\,(\mathbf{y})\,,$$

where $prob\,(K)$ stands for the dichotomic variable (α) for the private capital, $\mathbf{y}$ for the vector of independent variables, and finally, ϕ is the probabilistic function used in the estimations. This procedure is repeated for the other variables used, changing adequately in each case the dependent and independent variables of the probit estimation.

4 Data Description

We use as a measure of per capita income Gross Domestic Product (GDP) for the period 1965-1995 across 50 Spanish provinces, excluding Ceuta and Melilla. Data comes from the *Fundación Banco Bilbao Vizcaya* (*Fundación* BBV, 1999). This institution provides a homogeneous GDP series from 1955 to 1997 at 1986 constant prices; we use population series, also from the *Fundación* BBV (1999) for normalization.[3]

For our conditioning exercise, we use private capital, human and public capital stocks and a measure of sectoral structure. Figure 1 shows the evolution of these variables across provinces and the period of examined.

[Insert Figure 1]

Private capital stock series is measured as the sum of all private activities (*Fundación* BBV, 1999). Series are in millions of pesetas at 1986 constant prices. The distribution of private capital is bimodal in the initial and final year of our span (panel [a]), indicating polarization of economic activities. The group of provinces with a high stock of private capital create a mode around 1.5 in the private capital stock distribution; the remaining provinces are concentrated in the prominent mode, set around the Spanish average. Private capital levels experienced a period of convergence until 1981; after this year, some provinces accumulated more private capital than others. This process created a differentiated cluster, during the nineties, in the private capital distribution.

We use two measures of human capital stock. First, we use a weighted measure of the total number, in each province, of workers with different levels of education attained. Following Mincer's work (1974), which relates the salary obtained to the level of education and training, we measure human capital as:

$$H_i = e^{\gamma S_i} L_i, \tag{13}$$

where H_i is the human capital stock, γ is the average returns on schooling, L_i is the overall level of workers in province i, and S_i is the average years of schooling of the working population in each province, measured as:

$$S_i = \sum_s n_s \frac{W_{is}}{L_i}, \tag{14}$$

where s represents the level of instruction attained, n_s is the number of years necessary to obtain the s_{th} level of education, and W_{is} is the number of workers in province i with a level of education s.

Data on the number of workers for each level of studies is from the *Institut Valencià d'Investigacions Econòmiques* (IVIE). We take five levels of education into acccount; the corresponding numbers of years necessary to obtain the s_{th} level of education (n_s) are: illiteracy (0), primary school (3, 5), secondary school (11), university (16), and the higher degrees of university or college graduates (17). As a measure of returns to schooling, γ, we use the estimate of Alba-Ramírez and San Segundo (1995), who calculate the Mincerian specification of earnings equation in Spain, obtaining a value of 8.36%, which does not substantially differ from the 8.5% estimated for Europe (see Psacharopoulos, 1994).

The distribution of this measure of human capital stock was bimodal in 1965 (panel [c] in figure 1), with two differentiated clusters of provinces (above and below the Spanish average). Over time, those provinces with low human capital concentrated in a more distant cluster than in 1965. The more accentuated bimodal

[3] The *Fundación* BBV (1999) data base is on a biannual basis; for our purposes this characteristic does not affect the results because we estimate the densities at each point in time. Moreover, following Quah (1997), we have calculated the ratio between the per capita value (in each year and for each province), and the per capita average for Spain. This normalization is very useful in two aspects. Firstly, it is an easy way to abstract from Spain's total growth and fluctuations. Secondly, since the average for Spain is equal to one, the data assumes the form of dispersion around the Spanish average, and it is possible to make direct comparisons across years.

shape of 1995 human capital distribution is characterized by some provinces moving towards the Spanish average, leaving behind the cluster of provinces endowed with relatively less human capital.

As a second measure of human capital we use the number of workers with "college graduate" education. In using this proxy, our aim is to study the effect of high levels of education on growth processes. Notice that this variable is completely differently distributed when compared to the other measure of human capital (panel [d]). Although there was a process of homogenization of the distribution across Spanish provinces, the distribution presents a long right tail, indicating that a few provinces concentrate a high number of workers with college graduate studies.

Public capital stock is expressed in millions of pesetas at 1986 constant prices. We define the total public capital stock as the sum of all types of public capital, which includes two main groups: productive public capital (infrastructures in roads, highways, water and sewer systems, urban infrastructures, harbors, railways and airports) and social public capital (health and education infrastructures). Its distribution (panel [b]) shows two modes in 1965, with a few provinces endowed with high stocks of public capital. In 1995 the provinces are concentrated in a prominent mode; a few provinces create a cluster, set at twice the Spanish average. From 1965 to 1995 provinces from both tails of the distribution tend towards the Spanish average. In general, "poor" provinces are endowed with a higher level of public capital; this confirms the idea that public capital stock has been used by government to develop depressed areas.

Finally, we construct an index capturing the sectoral composition of each province (see, Dowrick and Gemmell, 1991). We use the provincial Gross Value Added (GVA) series in millions of pesetas at 1986 constant prices, disaggregated into the three main sectors of the economy: agriculture, forestry and fishing; industry, energy and construction; and services (*Fundación* BBV, 1999). We use the series of workers in each sector (IVIE). The index is constructed as:

$$I_{i,t} = \frac{\frac{GVA_{i,t}^{Ind}}{L_{i,t}^{Ind}} + \frac{GVA_{i,t}^{Serv}}{L_{i,t}^{Serv}}}{\frac{GVA_{Spa,t}^{Ind}}{L_{Spa,t}^{Ind}} + \frac{GVA_{Spa,t}^{Serv}}{L_{Spa,t}^{Serv}}}. \quad (15)$$

5 The Evolution of the per capita Income Distribution

Figure 2 shows results that summarize the evolution of the per capita income distribution across the Spanish provinces. Panel [a] compares the density estimates for 1965 and 1995; panel [c] presents their smoothed differences, which help to characterise the processes of convergence and growth. Panels [b] and [d] show, respectively, an estimate of the evolution of the density between 1965 and 1995 and its contour plot. Finally, panel [e] presents the relative position of each of the provinces in 1965 and 1995.[4]

[Insert Fig 2]

In 1965 the distribution shows three groups of provinces, clustered around 0.7, 1 and 1.5 of the relative per capita income distribution.[5] In 1995 the income distribution has less variance; moreover, provinces are clustered into two groups. The smoothed differences plot shows that those provinces set on both tails of the distribution have converged to the centre, but creating two different clusters (above and around the Spanish average). Therefore, we observe a process characterized by both absolute and club convergence.

[4]The contour plot of the bivariate density estimation of the joint distribution for two years (panel [e]), gives the dynamics between these two particular years. All observations below the 45-degree line (dashed) correspond to provinces that lost positions in the income distribution from the year represented in the x-axis with respect to the year in the y-axis. Of course, the argument is the opposite looking at points above the 45-degree line. In the appendix, table 1 indicates to which province each number corresponds. For more details on inter and intra distributional dynamics for the Spanish case, see Leonida and Montolio (2001).

[5]For clarity reasons, we have labelled provinces in three main categories: "poor", "middle class" and "rich" depending on wether their per capita income was below, around or above the Spanish average, respectively.

This may be surprising since absolute and club convergence have been seen in the empirical literature as competing hypotheses. However, it seems reasonable that in a general process of convergence involving all provincial economies, developed provinces may converge faster towards one another, forming groups and separating from the others (club convergence). This does not exclude the possibility that such clusters may converge (absolute convergence) or diverge (absolute divergence).[6] In contrast to Gardeazábal (1996) and Lamo (2000), we found an overall process of convergence and polarization of income (club convergence) across the Spanish provinces during the period 1965-1995.

These results do not change if we perform robust estimations of the per capita income distribution. We re-estimate the densities with a 15% deviation from the optimal Sheather-Jones bandwidth used in the estimates presented in figure 2. We also calculate averages for each decade, to remove short run effects of fluctuations. Results of these exercises are reported in figure 3: panels [a] and [b] present the estimates of 1965 and 1995 with ±15% of the optimal bandwidth; panel [c] presents the 3D evolution of the income distribution for averaged years, and panel [d] is the comparison between the density estimate for the time average 1965-1969 and 1991-1995. Moreover, we perform all the density estimates and the robustness exercises using the Cross-Section Least-Squares bandwidth (figures not reported).

[Insert Fig 3]

The convergence pattern found was not, and is not uniform; periods of convergence may have been followed by periods of divergence. The methodology employed allows us to determine endogenously the relevant periods and not to take them as given, as in other studies. Panels [b] and [c] show that the overall period may be decomposed into four sub-periods in which the dynamical path of the provinces is substantially different.[7] From 1965 to 1977 the provinces experienced a period of convergence: per capita income of those provinces grouped around 0.7 of the income distribution increased to 0.8, approaching the middle class, while rich provinces lost relative positions, also approaching the middle class (from 1.5 to 1.4 in the per capita income distribution). This result is in contrast with the evidence presented by Dolado, González-Páramo and Roldán (1994), who found for a similar period (1994-1977) no evidence of convergence, but in line with Goerlich et al. (2001), who pointed to convergence in labour productivity across provinces as a possible factor explaining this process.

A second period runs from 1977 to 1983. Over these years there was a process of polarization of income: the convergence process observed in the previous period came to an end. In 1983 there were two clusters of provinces, mainly because the rich provinces continued to lose positions, approaching the middle class. Particularly significant is the loss of positions of those provinces (mainly in the Basque Country) that suffered the decline of the industrial sector.

In a third period, running from 1983 to 1993, some of the middle class provinces shifted to the poor group and some grew enough to approach the richest group of provinces that, in turn, were concentrating at a lower level of the relative per capita income distribution. This process leads to a "vanishing middle class", and therefore, a polarization process.

Over the last years analysed (1993-1995) provinces continued to cluster in two differentiated groups, and began to diverge. In 1995 the income distribution shows a second mode, emerging at about 1.2 of income distribution. Moreover, a divergence process can be also detected over the nineties: the richest provinces not only create a significant mode, but also separate from the other group of provinces (note that the distance between modes was greater in 1995 than in 1993).

We complete and enrich our analysis by individuating those provinces which have changed cluster in the income distribution through time. Panel [e] in figure 2 shows the relative position of each of the provinces in 1965 and 1995. These results confirm our previous findings. The rich provinces in 1965, which had an income per capita higher than 60% of the Spanish average, have lost relative positions; however, in 1995

[6] Leonida (2002) shows that testing for convergence using absolute and club convergence as competing hypotheses is intuitively appealing, but may be misleading: evidence in favour of the latter may or may not reject the former.

[7] In figure 2 panel [d] the vertical axis indicates the 16 years available in the biannual data base (from 1965 to 1995).

they still compose the rich cluster showing persistence in relative positions and income disparities (Álava, Baleares, Barcelona, Girona, and Madrid). Especially significant is the evolution of Guipúzcoa and Vizcaya: from the highest part of the distribution in 1965 to lower positions much closer to the Spanish average (but still forming part of the rich cluster in 1995). Moreover, in 1995 these provinces are matched by eight other provinces; five from the middle-income class in 1965 (Lleida, Navarra, La Rioja, Tarragona and Zaragoza), and only three from the poor cluster (Burgos, Castellón and Guadalajara): all of them forming the separated and diverging cluster observed in recent years.

The provinces composing the middle-income class in 1965 split also because four of these provinces moved to the poorer group (Alicante, Oviedo, Santander and Sevilla). The poor provinces, in general, gained positions in the income distribution (except Cádiz); however, not all of them grew enough to change cluster. Five provinces switched from the lowest part of the poor cluster to the upper part of the same group (Ávila, Cáceres, Soria, Teruel and Toledo).

Finally, it is worth mentioning that we do not estimate the ergodic distribution from the realised random fields. This is for two reasons. First, we prefer to estimate the effects of different variables on the evolution of the actual distribution (see next section). Second, because this exercise has been performed by Lamo (2000), and there is no reason to expect any different characterization of the steady state *given the time structure of the transitions she uses*. This is exactly the point we raise. Losing 6% in the relative per capita income distribution took the richest provinces more than 10 years; changing cluster involved a process lasting 20 years for the poor provinces. Therefore, interesting long-run changes occurred in the Spanish income distribution. However, given the persistence that per capita GDP series usually shows, a framework studying one year transitions (such as Lamo, 2000) clearly must have persistence of income inequalities as its main result. Such a framework tends to hide interesting features of the growth process; for instance, figure 2 leads to more detailed and reasonable conclusions. Furthermore, being a measure of the persistence of the sample, results from a stochastic analysis may be misinterpreted: both Gardeazábal (1996) and Lamo (2000) conclude that provincial economies are in their steady state positions. However, the simple representation of the growth and convergence process in panel [e] in figure 2 shows that none of the provinces is set on the 45 degree line, and this raise some doubts whether they are in a steady state position or not.

We believe that the steady state positions of economies should be characterized in terms of economic theory, rather than by means of a purely empirical approach. As Quah (1996c) has pointed out, it is necessary to provide explicit economic models to support the recent empirical evidence based on the statistical quantification of changes in the income distribution.

6 The Effects of Growth Determinants on the per capita Income Distribution

In this section we present the counterfactual results.[8] Each figure contains five panels. We report the actual distribution and its re-weighted counterpart for 1995 (panels [a]) and 1965 (panels [b]) to test the hypothesis that the effect of each of the growth determinants on the distribution can change over time. Panels [c] and [d] show the difference between each actual and counterfactual distribution. We also present a 3D estimate of counterfactual densities estimated for all available years (panels [e]), and the evolution of the departure of such counterfactual densities from the actual distributions (panels [f]).

Does Private Capital Accumulation Represent the Main Source of Growth?

In answering this question, first we focus on the effects of private capital on the income distribution. Private capital accumulation is suggested to be the main determinant of growth, according to both neoclassical frameworks of growth (Solow, 1956 or Mankiw, Romer and Weil, 1992) and endogenous growth theories (Romer, 1986). As we noted, the analysis of the distribution of private capital stock suggests that there exist some structural differences across provinces with respect to their ability to accumulate private

[8]We have only reported the counterfactual densities for the case when $\alpha = 0$ because the counterfactual densities for $\alpha = 1$ are a mirror image.

capital. Now we study what the distribution of incomes would look like if the effect of this ability were removed.

To answer this question, we attach 1 to observations having a high level of private capital stock and 0 to all others, and estimate the probability (using a probit model) of being endowed with high private capital as a function of the full vector of independent variables.[9] This procedure results in the vector of weights $\hat{\theta}_i$, see equation (10). The weights are used to answer the question of interest, which is reported in figure 4.

[Insert Fig 4]

Our exercise suggests, as expected, that the accumulation of private capital plays a crucial role in growth and convergence processes. The estimated counterfactual densities have less variance, and the multiple regime of the actual per capita income distribution vanishes: the provinces would be concentrated in a single cluster, settled below the Spanish average.[10] This effect is greater for the rich provinces. The smoothed difference for 1995 shows that these economies would lose positions, moving to the lower part of the income distribution. In 1965, the counterfactual distribution is characterized by the middle class and rich provinces concentrating in the lower part of the income distribution; however the division into two groups is still in evidence. Therefore, private capital accumulation explains an important fraction of the processes of growth of developed economies in Spain. The ability to accumulate private capital enabled a fraction of provinces to grow and to separate from the rest of the observations.

Panels [e] and [f] show that for most of the period private capital has the effect just described. In some years, it causes polarization of income into two groups. This second effect is evident especially over the middle 80s, when the private capital stock distribution is unimodal, indicating that when this variable is equally distributed, the rich provinces still create a separated cluster, possibly because of the effects of other growth determinants.

Does Human Capital Substitute for Private Capital in Growth Processes?

There is a vast literature arguing that human capital can induce growth. Human capital has been introduced into theoretical models either as a vehicle of endogenous growth (Lucas, 1988) or directly into neoclassical production functions as a productive input within a broad definition of capital (Mankiw, Romer and Weil, 1992).

The question that interests us here is: "What distribution of incomes would prevail if the distribution of the human capital stock were equalized across provinces"? Our results are reported in figure 5.

[Insert Fig 5]

The effects on growth of the first human capital variable used are positive, especially in the initial years of our database. However, its effects on the per capita income distribution are smaller than the effects of private capital stock.

Human capital has a greater effect in those years when the Spanish provinces still did not have a highly developed educational system. In 1965, for example, education was not as diffuse as it is today; skilled workers were concentrated in the rich provinces, making big differences in terms of production. In recent years, the counterfactual distribution shows the same characteristics of the actual distribution but even more pronounced: polarization of income in two differentiated clusters. This indicates that the rich provinces may be benefitting from other growth determinants. In short, we believe that the change in the effects over time,

[9] "High" and "low" levels have been decided on the shape of the per capita private stock distribution itself. In this context, non-parametric density estimates are used, as suggested by Silverman (1986), as discriminant analysis. The same procedure is used for the other variables.

[10] The opposite counterfactual (not reported) aso shows convergence but at a higher level of the relative per capita income distribution.

bigger over the sixties and seventies and smaller in more recent years, can be explained by a generalization of the level of education among the Spanish working population.[11]

As a confirmation of this analysis, we obtain different results if "college graduates" are used as a proxy of human capital (figure 6).

[Insert Fig 6]

In 1995 the distribution would change from a bimodal (actual) to a unimodal shape (counterfactual). This indicates that the polarization found in the 1995 income distribution is partially caused by the unequal distribution of college graduates across provinces.

Instead, in 1965 the counterfactual density shows an income distribution with less variance but still with two differentiated clusters. In 1965 the number of graduates was not large enough to make the distribution completely unimodal, and the rich provinces, although having the same distribution of graduates as those provinces with less graduates, would still create a differentiated cluster. Even though the time evolution of the counterfactual densities is quite bizarre (panel [e]), we can observe that in recent years, the effect of this variable is to create a unimodal distribution. Therefore, it seems that the effect of workers with graduate studies explains part of the polarisation of income across the Spanish provinces in recent years.

Summarizing, human capital stock has been an important variable in the growth and convergence processes observed across the Spanish provinces. During the sixties and seventies having an educated working population was an important growth determinant. The generalization of the educational system in Spain implied that in recent years this role has been played by workers with high levels of education.

Does Government Spending Stimulate Growth and Convergence?

Now we analyse one of the main puzzles in the empirical growth literature: the effect of public capital. In seminal works by authors such as Aschauer (1989) or Munnell (1990) public capital, under the control of governments, has been reported to have effects on the productivity of the economy, and hence, on growth rates. However, these results are controversial since in the growth regression framework its estimated parameters are not robust to different estimation techniques. Figure 7 presents the results from our conditioning exercise for public capital.

[Insert Fig 7]

In 1965 public capital has a negligible effect on the per capita income distribution; in recent years, however, public capital seems to have an effect on the per capita income distribution across the Spanish provinces.

These results can be interpreted as the consequence of the expansion of the public sector over time. In the initial years of our database public intervention in the form of public capital was not as diffuse as is today, and therefore its effect could not be other than negligible. In recent years, democratic governments have implemented a series of public policies leading to the construction of the Spanish welfare state: investment in public capital has increased and raised Spanish standards to European level.

The difference between the actual and the counterfactual estimated income distributions for recent years can be interpreted as public capital having a positive impact on convergence but a detrimental effect on growth. The counterfactual distribution in 1995 is more unequal (two more distant clusters) than the actual distribution: the rich provinces would be richer if public capital was equally distributed across provinces. Interestingly, even the poor provinces would be, on average, richer than they are today. Therefore, if public capital were uniformly distributed across provinces (after controlling for the other variables), this would

[11] de la Fuente (2002) reaches similar conclusions regarding the empirical effect of human capital on growth.

induce the rich provinces to separate more from the poor provinces, obtaining a more unequal distribution of per capita income.

We interpret these results in the light of two effects: redistribution and growth effects. The public sector is less effective than the private sector in producing goods and services; therefore, shifting resources from the private to the public sector tends to reduce the growth process. However, because public sector redistributes income from rich to poor provinces (creating an unequal distribution of public capital, see panel [b] in figure 1) the actual distribution is less unequal than the counterfactual one. In this sense, public capital promotes convergence (redistributing incomes) but has a negative effect on growth especially across the rich provinces (possibly through taxation). It is important to note that even if this seems to be a small but positive effect of public capital on convergence, it is not strong enough to create an equal distribution of income.

These two opposite effects of public capital (equity versus efficiency) could be the reason why the estimated average effect of public capital, measured for instance by means of OLS or panel data techniques, may result to be negligible or even negative.

Does Industrialisation Matter?

If private, human and public capital have been widely introduced into theoretical models as growth determinants, it is more difficult to establish the effects of changes in the sectoral structure on growth. Some empirical studies for the Spanish case have used different measures of sectoral structure to investigate its effects on growth and convergence dynamics (for instance, Raymond and García-Greciano, 1994, Serrano, 1999 or de la Fuente and Freire, 2000).

We use a common index of industrialisation to show the effects on the income distribution of a shift of resources from agriculture to other sectors of the economy. Figure 8 presents the estimated counterfactual densities, showing the distribution of incomes that would prevail if all the provinces had had enjoy the same sectoral structure as those provinces with an economy more dedicated to the agricultural sector.

[Insert Fig 8]

In 1965 the estimated counterfactual effect is very small, possibly because over these years the economic structure in Spain was concentrated in agricultural activities. In recent years, the sectoral structure has shifted towards industry and services; therefore, in 1995 the counterfactual estimate presents a more uniform distribution, even though a rich cluster in the highest part of the per capita income distribution still exists.

A general, and partially surprising, result is that industrialisation has little effect on the income distribution. However, we measure industrialisation as the shift of resources from the agricultural sector to the other sectors, holding constant all other variables among which, for example, private capital accumulation is included. Clearly, industrialisation drives not only private but also human and public capital accumulation (changing the structure of the economy), and therefore we should first estimate the effects of industrialisation on capital accumulation, and subsequently the effects of this “inducted” accumulation of capital on growth. In other words, we think that the important estimated effect of capital accumulation on growth depends on industrialisation; however, it is difficult to decompose these effects with adequate precision.

7 Conclusions

This study has enabled us to reach a number of interesting conclusions that we believe can shed some light on the growth and convergence debate in Spain.

First, the use of recent data allows us to conclude that, within an overall process of convergence, the Spanish provinces have alternated periods of convergence and periods of polarization of income and divergence. In recent years, club convergence seems to have combined with an incipient period of divergence.

During the 60s, the poor provinces converged towards the Spanish average income. At the same time, the rich provinces lost positions in the per capita income distribution. This finding completes previous studies claiming absolute convergence: the convergence process observed during the sixties was mainly caused by the rich provinces losing positions together with the middle class and poor provinces converging towards one another. However, over the 70s, the convergence process halted: some provinces from the middle class grew and caught up with some rich provinces while the latter continued to lose positions (creating together a new cluster in the income distribution). Over the 80s, this middle class vanished (polarisation of income). Some of these provinces lost positions in the per capita income distribution and joined the poor provinces; the remaining grew enough to approach the rich provinces. Subsequently, over the 90s the main group of provinces did not change their relative position; some of the provinces from the middle class caught up with the richest ones, creating a new cluster at 1.2 of the income distribution. This implies not only a process of polarization of income into two groups, but also an initial process of divergence: the two modes begin to separate.

Second, the methodology employed allows us to individuate with precision the evolution of each province within the income distribution. The rich provinces lost many positions in the per capita income distribution, this evolution being specially accentuated for provinces in the Basque Country (especially Guipúzcoa and Vizcaya). On the other hand, the poor provinces remained in the poor part of the distribution, except for Guadalajara, which grew enough to move from the poor part of the income distribution in 1965 to the rich cluster in 1995. Interestingly, the movements of provinces with per capita income around the Spanish average ("middle class") determined many of the convergence and polarization processes observed in Spain.

Third, analysing the reasons why some provinces have grown more than others can help policy makers to formulate adequate policies to address the issue of income disparities across provinces. Therefore, our analysis aimed to discover which factors led to the actual evolution of the per capita income distribution, an evolution clearly linked to the changes over time in the classical factors of production.

In general, the regression framework normally used to estimate the average growth effects of "potential" growth determinants such as private capital results in estimated parameters that are a weighted sum of the effect of this variable on the poor provinces (which effect may be expected to be negligible) and on the rich provinces (which effect may be expected to be strongly positive). The econometric framework we define demonstrates that, private capital being mainly concentrated in the rich provinces, its distribution can explain a substantial part of the actual difference between "poor" and "rich" provinces in Spain. It seems therefore that is the ability to accumulate private capital that permits provinces to grow, and therefore, separate from those that have less private capital.

Human capital stock also has an effect on the actual income distribution. Education at a graduate level can account for, in recent years, part of the polarisation process observed across the Spanish provinces, while in the initial years of our database it seems that it was the weighted measure of human capital that played a more important role in growth and convergence processes in Spain. This can be explained by the low level of general education in Spain during the sixties and seventies, and the posterior development and generalization of the educational system during the eighties and nineties.

Public intervention has been directed to develop poorer provinces. However, the relationship between per capita income and public policies is much less obvious. On the one hand, intervention by public capital allows poor provinces to improve their standard of living (*via* redistribution of incomes). On the other hand, it seems to reduce the growth rate of rich provinces (*via* taxation). Both effects combined could be the reason why this variable has been one of the main puzzles in the empirical literature on growth. Finally, the sectoral structure of provinces seems to have a less important effect on the distribution of income.

Of course, our exercise does not explain the total variability and polarisation of incomes; both because we did not concentrate on variables such as financial development, and because a relevant part of income variability is explained by historical events, which affect both the evolution of the per capita income distribution and the evolution of growth determinants.

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9 Figures and Tables

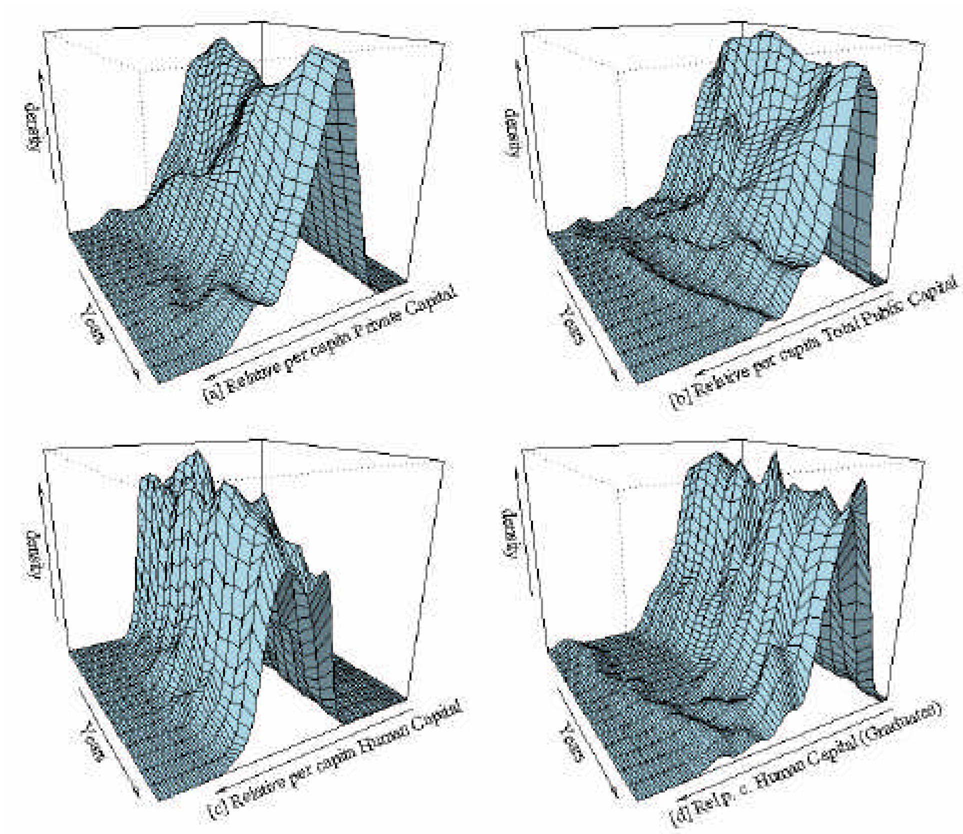

Figure 1: Growth determinants evolution across provinces and years.

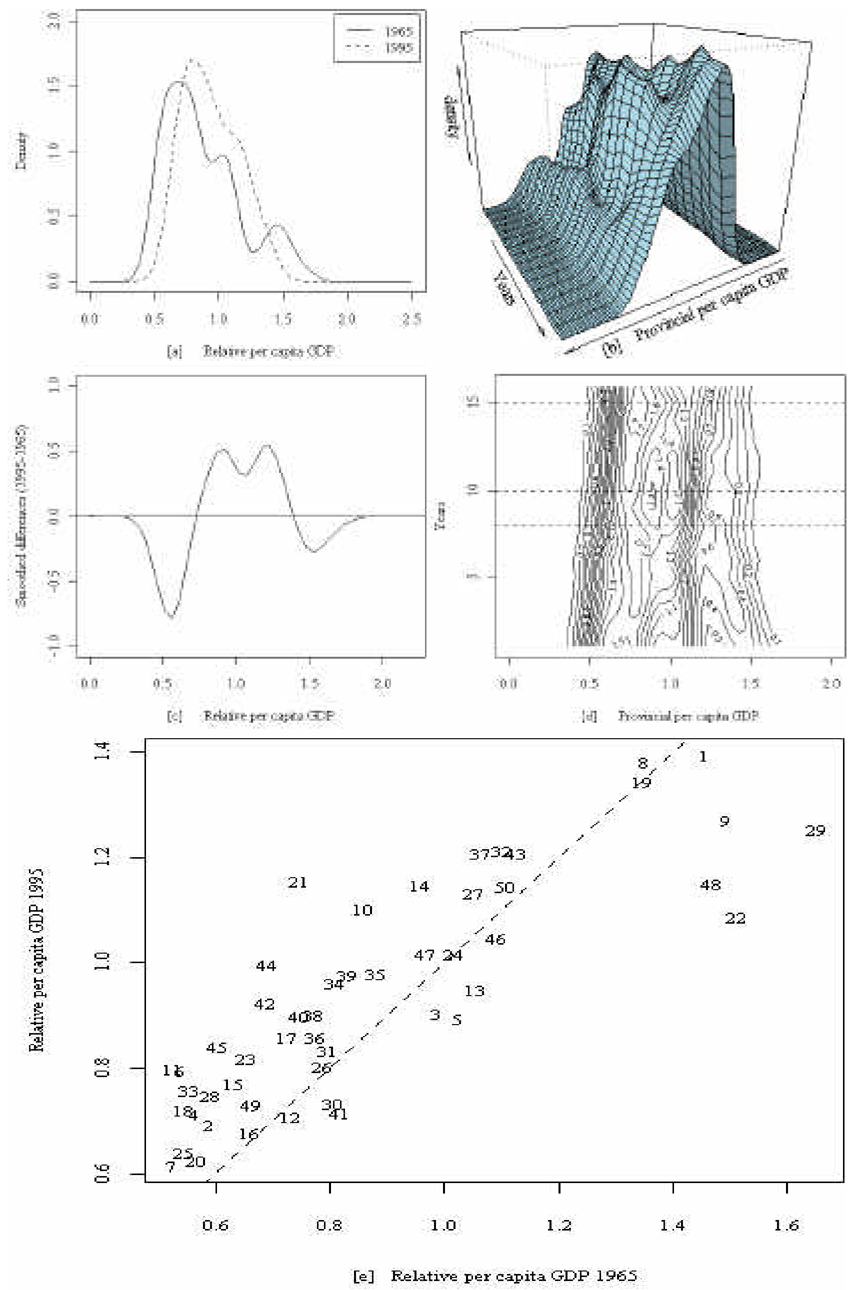

Figure 2: Evolution of relative per capita incomes across provinces and years.

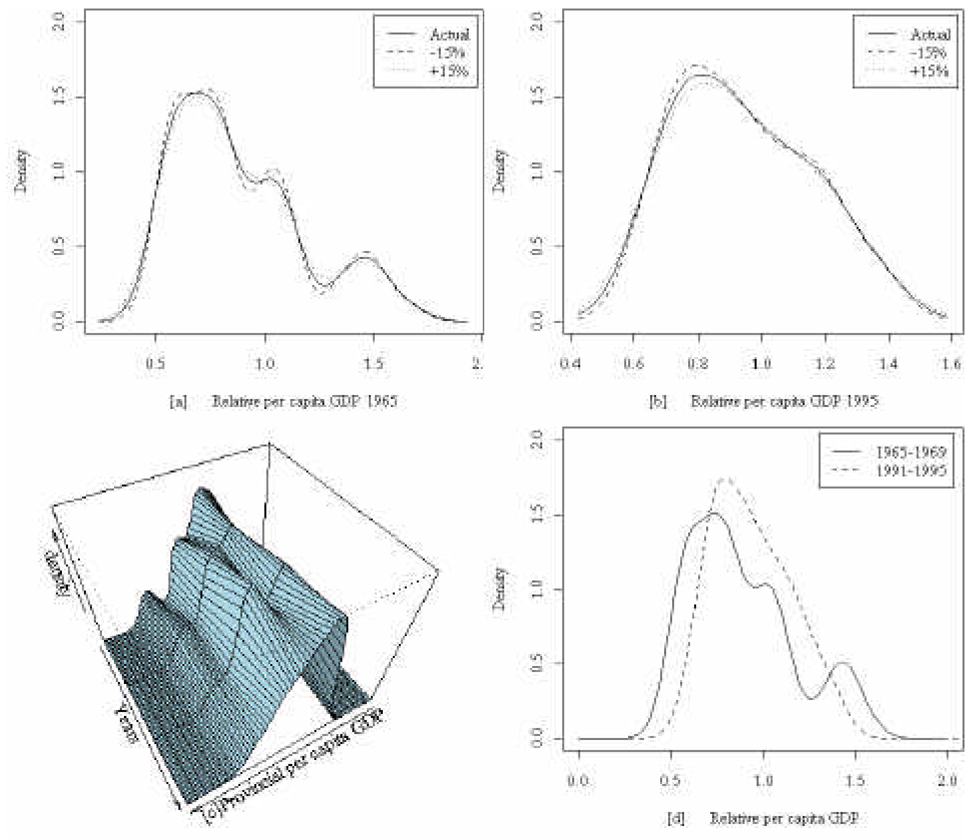

Figure 3: Robustness exercises

Table 1. The Spanish Provinces

1. Álava	14. Castellón	27. Lleida	40. Segovia
2. Albacete	15. Ciudad Real	28. Lugo	41. Sevilla
3. Alicante	16. Córdoba	29. Madrid	42. Soria
4. Almería	17. Coruña (A)	30. Málaga	43. Tarragona
5. Asturias	18. Cuenca	31. Murcia	44. Teruel
6. Ávila	19. Girona	32. Navarra	45. Toledo
7. Badajoz	20. Granada	33. Ourense	46. Valencia
8. Baleares	21. Guadalajara	34. Palencia	47. Valladolid
9. Barcelona	22. Guipúzcoa	35. Palmas (Las)	48. Vizcaya
10. Burgos	23. Huelva	36. Pontevedra	49. Zamora
11. Cáceres	24. Huesca	37. Rioja (La)	50. Zaragoza
12. Cádiz	25. Jaén	38. Salamanca	
13. Cantabria	26. León	39. Sta. Cruz Tenerife	

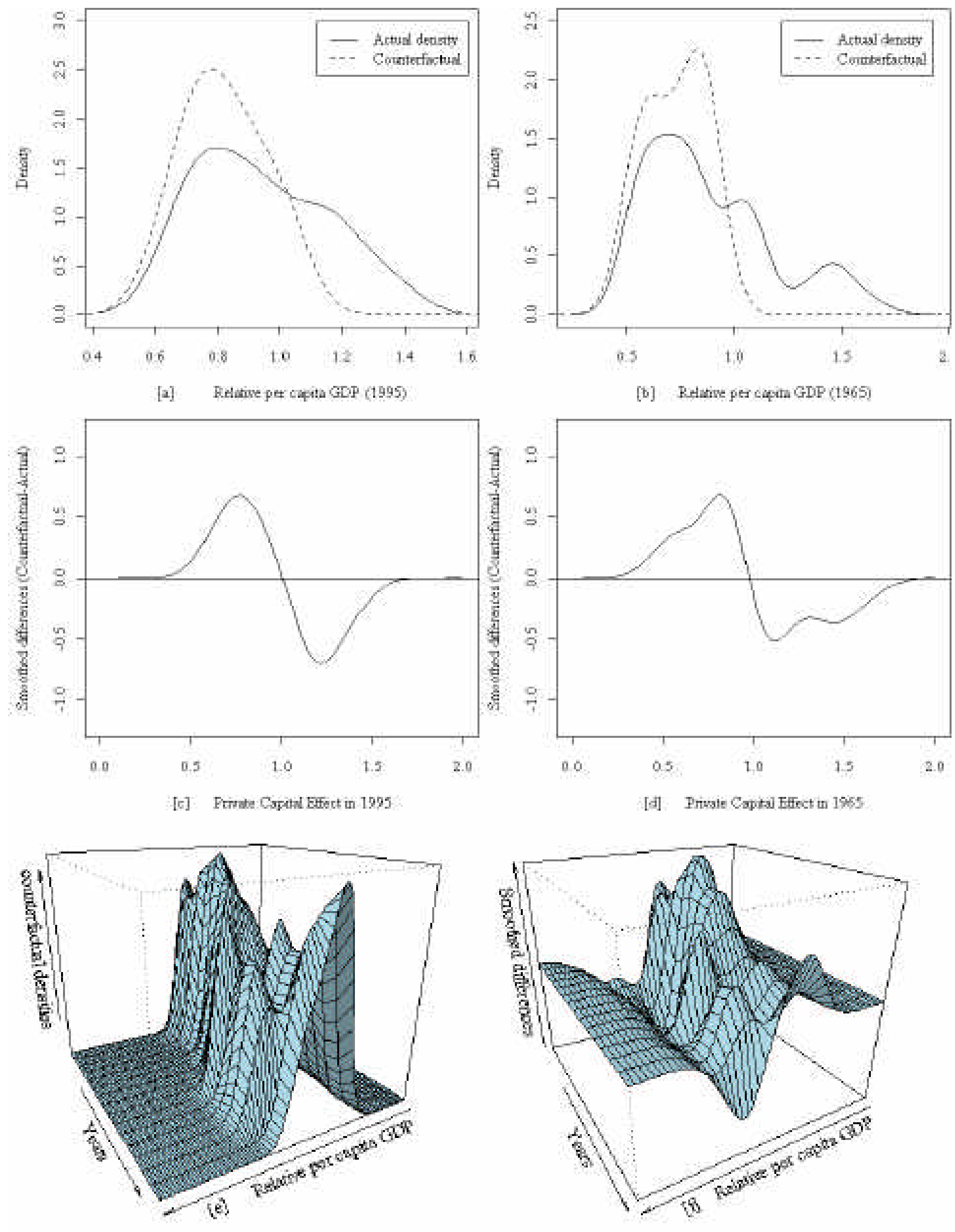

Figure 4: Accumulation of private capital, growth and convergence

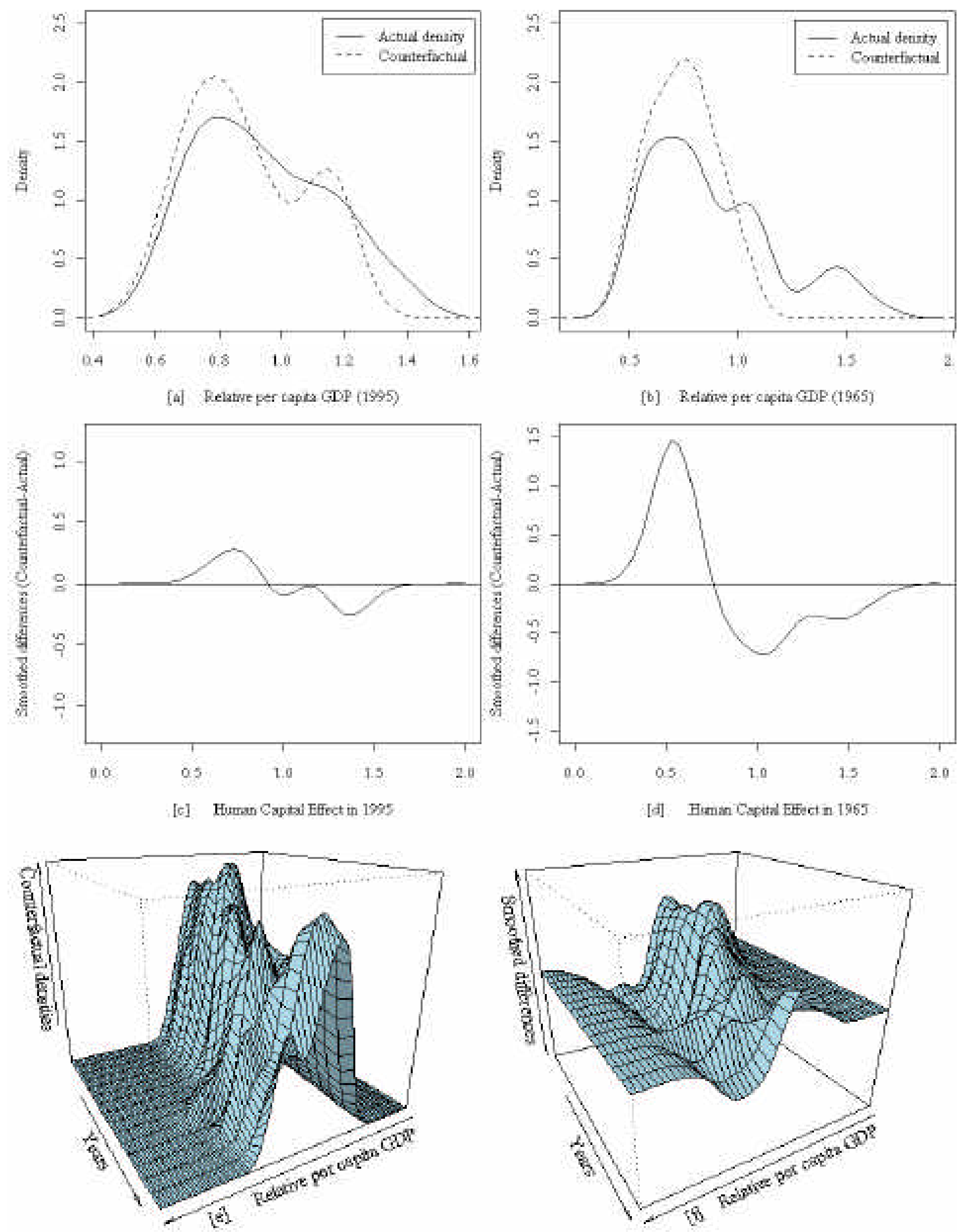

Figure 5: Human capital and distribution of incomes

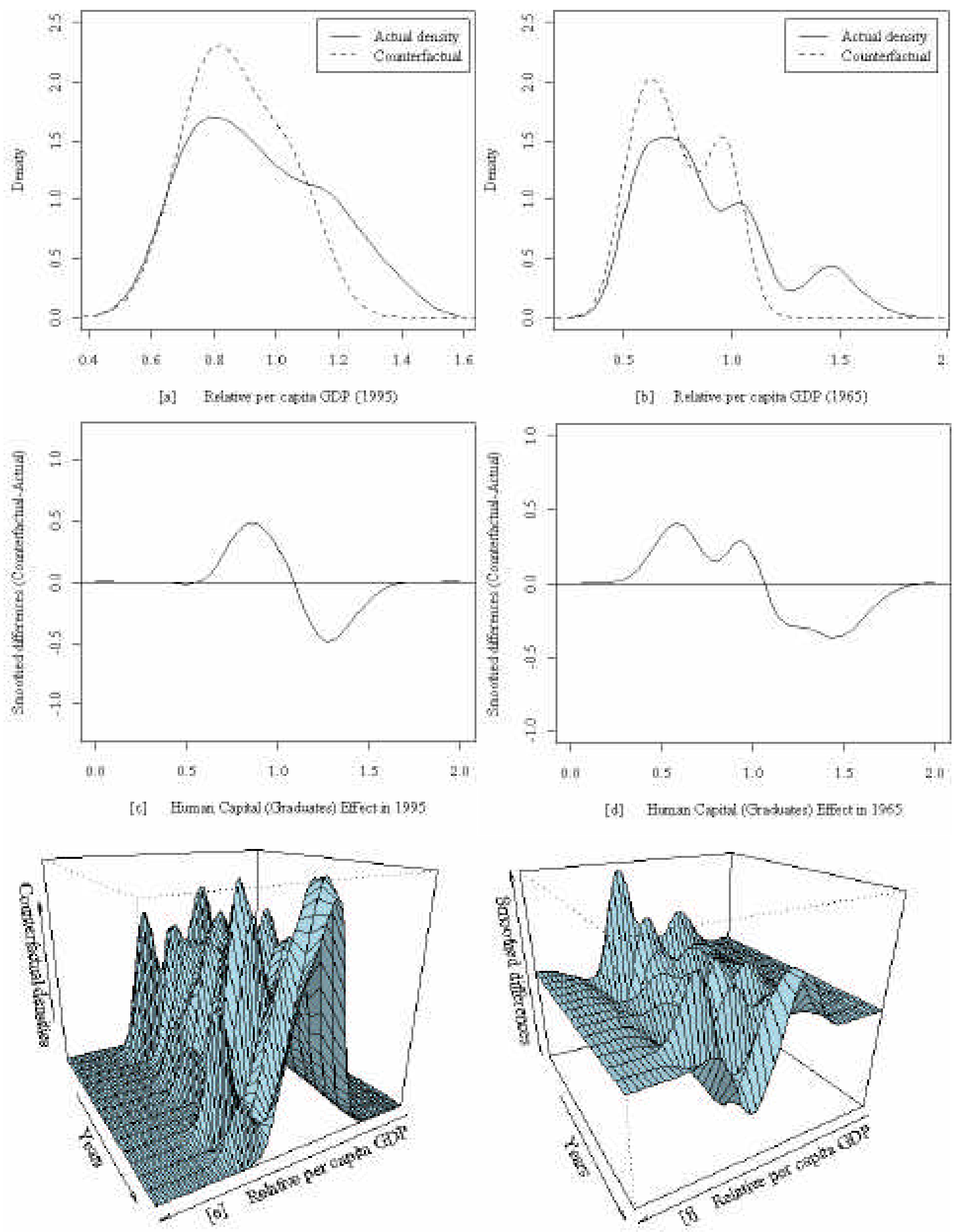

Figure 6: Graduate education and growth

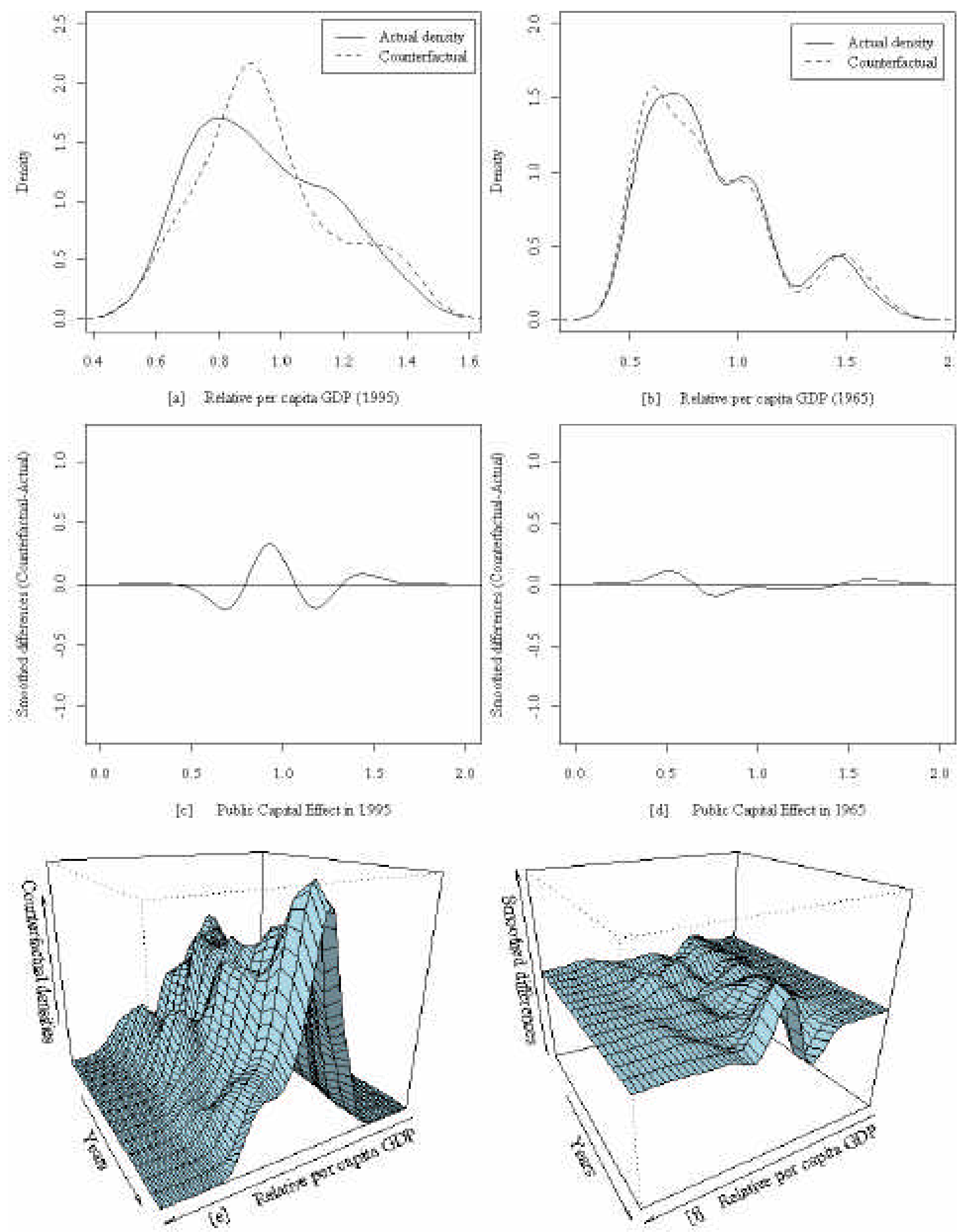

Figure 7: Public capital and redistribution of incomes

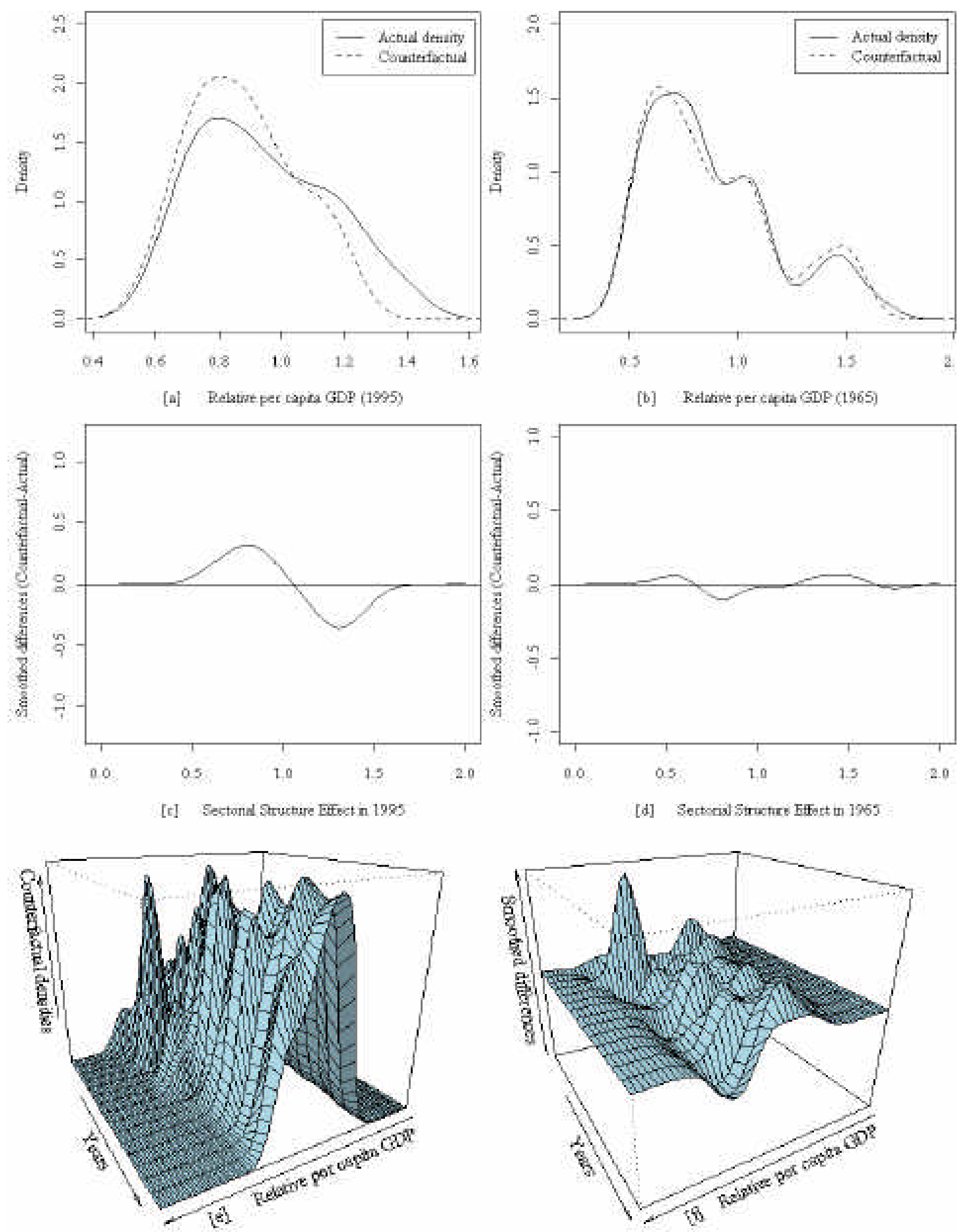

Figure 8: Does industrialization matter?

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