CONVERGENCE AND PUBLIC INVESTMENT ALLOCATION
SPAIN 1980-93

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D-99001

Febrero 1999

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We would like to thank Rafael Doménech, Javier Escribá, Angel de la Fuente, Teresa García-Mila, Jorge Padilla and Martín Peitz for useful comments. Ana Lamo acknowledges the financial support fiven by CICYT grant PB96-0339.

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Abstract

This paper studies the impact of public investment on the convergence process of labor productivity across Spanish regions during the period 1980-93. Our approach is to ask how labor productivity would have evolved across Spanish regions in the absence of public investment and under different public investment scenarios. These scenarios consist of re-allocating the national public investment according to several criteria, this will generate alternative stocks of public capital, different from the observed ones (*virtual public capital*). Then, using the estimation of a regional production function in which public capital is included, we recover labor productivity under the new public investment allocation *(virtual labor productivity)*. Finally, we study the convergence process for both, observed and virtual productivity. The convergence analysis is carried out in the context of cross-section distribution dynamics.

The dynamics of observed labor productivity across Spanish regions (1980-93) shows a considerable persistence. The more productive regions slightly approach the national aggregate ('average') while the less productive ones do not improve positions. In the short-run public investment has contributed to increase the positive deviations of the most productive regions. Investment re-allocation based on an efficiency criterion would have increased the disparities across regions, and a purely re-distributive criterion would have contributed positively towards convergence. The observed policy resembles an allocation criterion based on population, physical size, population dispersion and geographic features.

Introduction

This paper analyzes the impact of public investment and its allocation on labor productivity across Spanish regions. How public investment in infrastructure influences the growth and convergence processes is a key question for policy design.[1] Public investment may act directly on the growth process, contributing to aggregate growth in the region. This has been studied in the empirical literature by estimating production functions in which public capital is one of the arguments (Aschauer (1989), Holtz-Eakin (1992) and Hulter & Schwab (1993) for the US and Màs *et al.* (1996), Dabán & Murgi (1996) and De la Fuente (1996) for Spain). There is also an indirect impact of public investment on growth by increasing/decreasing the productivity of the private sector. Several recent papers address this issue: Pissarides and Wasmer (1997), Bean (1997).[2] Concerning the convergence process, public investment is important since it may have effects at the inter-regional level, increasing for example the average productivity of the poorest regions and consequently acting as an instrument of redistribution that helps to reduce the regional disparities.

We will focus on the inter-regional effect and examine whether the convergence process would have been different in the absence of public investment and under alternative regional allocations of public investment. That is, whether public investment and/or its allocation can account for part of the labor productivity dynamics across Spanish regions.[3] As far as convergence is concerned our analysis is based on cross-section distribution dynamics.

The paper comprises three parts: in the first part we study the convergence process across 17 Spanish regions. The framework of analysis consists of studying the dynamics of the cross-economy labor productivity distribution along time following Quah (1993, 1996, 1997).[4] The second part is the core of the paper. There we discuss the role of public investment. We estimate a regional production function where regional public capital is

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1 Public investment in this paper refers to investment in infrastructure. In other words, productive public investment, which excludes spending on education and health. The reason is that the economic effects of education and health are long term and not necessarily confined to the region were the investment happened. Notice that in Spain most of the investment in infrastructure is carried out by the public administration but there exists some para-state organizations which produce part of the infrastructure, for more details on this see section II.2.

2 They debate on whether public and private capital are substitutes or complementary inputs.

3 De la Fuente & Vives (1995) and de la Fuente (1997) analyze similar issues under a different approach.

4 For more reading on empirics of convergence see *The Economic Journal*, 106, July (1996).

one of the arguments and use it to simulate series of virtual labor productivity, i.e. the one that would have realized under the alternative public investment policies. In order to do so, we define different scenarios derived from alternative investment policies and also from the absence of public investment. We compute alternative series of public capital *(virtual public capital),* then using the estimated production function we recover the virtual labor productivity.[5] The dynamics of the distribution of virtual productivity compared with the dynamics of observed productivity gives us information on how public investment and its allocation affects convergence. In the third part we offer some summary and conclusions.

The main findings of the paper are that the dynamics of observed labor productivity across Spanish regions (1980-93) shows a considerable persistence. The more productive regions slightly approach the national aggregate ('average') while the less productive ones do not improve positions. In the short-run public investment has contributed to an increase of the positive deviations of the most productive regions. The investment policy followed during the 1980-93 has not substantially changed the relative public capital endowments from those in 1980. The observed policy resembles an allocation criterion based on population, physical size, population dispersion and geographic features (orography). A policy based on efficiency would have damaged convergence while a pure re-distributive allocation of public investment would have helped the Spanish regions to converge.

I. Labor productivity dynamics

I.1 Introduction

In this section we characterize the convergence process of labor productivity across regions in Spain, giving answers to questions like the following: are the less productive regions in Spain catching up with the more productive ones? How far (in terms of productivity) are the less productive regions with respect to the more productive ones?[6]

In order to do so, we follow the distribution dynamics approach. This approach has been developed recently by Quah to examine convergence. If convergence is understood as a process of economic homogenization (non-persistent inequality) then a natural approach to convergence is to study the dynamics of the entire cross-economy

5 The idea of virtual economies has been used by Marimon and Zilibotti (1994) among others.

6 Our final goal is to see how the answers to these questions change under different public investment

distribution of labor productivity along time. Nevertheless, most of the standard literature on convergence departs from this approach at least in two ways. First, it collapses the time dimension by averaging, thus summarizing the main features of the distribution in a few statistics, whose informational contents, with respect to convergence, are unclear. Second, it uses the framework of the representative economy model to draw conclusions about the entire cross-section.

Quah's approach encodes the standard one and overcomes some of its difficulties. It takes into consideration the whole cross-section distribution exploiting the interrelations across economies and does not impose any structure on the data, nature of convergence, trend, etc. It is able to account for transitional properties of the data and to characterize situations as convergence, polarization, stratification, etc.

This first part is organized as follows: section I.2 describes the data and variables. Section I.3 presents a first approach to the dynamic of distributions. Section I.4 sketches the Quah (1993, 1996, 1997) methodology and analyses labor productivity dynamics. Finally, section I.5 offers some conclusions.

I.2. Data and variables

The data are taken from the BD.MORES database elaborated by the Spanish Ministry of Economy and Finance, which ensures compatibility at the regional and sectorial level and over time. Output and its components are drawn from regional accounts and the series have been elaborated combining detailed information from several sources. Every nominal variable has been transformed into real terms.[7] The sample covers seventeen regions over a period of 14 years (1980-93). The regional disaggregates correspond to NUTS2 in Eurostat nomenclature of statistical territorial units. In Spain they are called *Comunidades Autónomas* (CC.AA.). Concerning the time sample, 1980-85 was a period of recession, and so was 1991-93.

Our basic variable of analysis is labor productivity (GDP per employee) of the productive private sector.[8] [9] We express the regional variables relative to the national ones.

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scenarios.

[7] The transformation into real terms has been done using regional price indices. See Dabán *et al* (1998).

[8] Notice that the evolution of labor productivity is affected by the peculiarities of the Spanish labor market, reflecting employment destruction (industry) and sectoral reallocation (from agriculture to services). Combining sectoral and regional analysis is on the agenda.

This normalization is a way to abstract each individual region from the overall growth and fluctuations.[10]

Let Y_{it} be the labor productivity corresponding to region i at period t and Y_{nt} the same variable for the country. We define Z_{it} as follows:

$$Z_{it} = \frac{Y_{it}}{Y_{nt}} \qquad \begin{array}{l} i = 1,\cdots,17 \\ t = 1980,\cdots,1993 \end{array} \qquad [1]$$

Z_{it} measures at each moment t the relative productivity position of region i with respect to Spain. Z_{it} larger than one indicates that the region i is more productive than the country in year t.

Figure 1: Relative Labor Productivity.
17 Spanish Regions. 1980-93

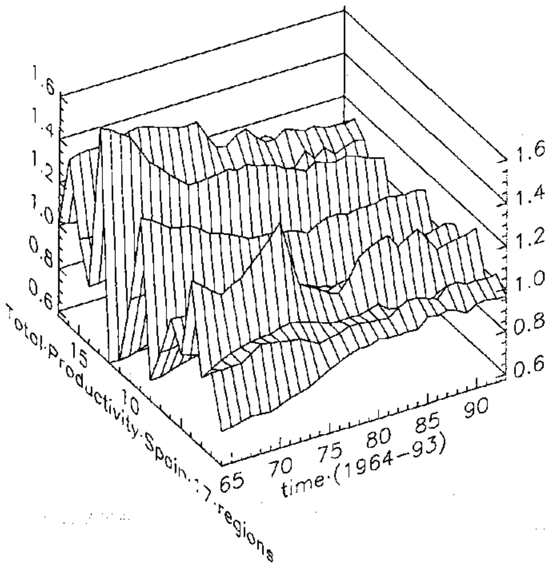

Figure 1 is a three dimensional plot of the variable for the 17 regions over the 14 years of the sample. It clearly shows that both dimensions of variation in the data appear to be very important.[11] It is precisely this two-dimensional dynamics that we are interested in.

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9 This includes GDP and employment from the private sector except housing rents.

10 The idea is to make the conclusion on convergence independent of the business cycle, although this requires that the regions move in the same way as the aggregate along the business cycle.

11 Taking averages, as the standard regression analysis does, is missing a significant amount of the

The idea is to consider the cross-section distribution of the variable of interest Z_{it}, at each point in time as the realization of a random element in a space of distributions, and to analyze its dynamics. The first step is to estimate the cross-section distribution of productivities at each point in time. The purpose of this exercise is to uncover any particular pattern in the time evolution of this distribution. In this context, the realization of the random element turns out to be a cross-section distribution function that has to be estimated from data. Notice that we are interested in the shape of the distribution. We must avoid imposing any prior assumption on it, or on the moments of the density function from which the data are drawn. This requires the use of non-parametric and semi-parametric methods. Unfortunately, seventeen cross-section observations do not allow us to use standard non parametric techniques. Figure 2 presents the Tukey boxplots for 1980, 1985, 1991 and 1993 which give information on the yearly dynamics of the interquartile rank.[12] They are a way of representing the observed cross-section distribution. Productivity appears on the vertical axis and time in the horizontal one.

Consider the first box from the left, the upper limit of the box is the top quartile (75th percentile) of the observed distribution in 1980. The bottom limit the 25th percentile. Consequently, the height of the box gives a measure of the spreading of the distribution (interquartile range). The middle horizontal line is the median, it provides information on whether the distribution is skewed or symmetric. Vertical lines upwards and downwards from the box are called upper and lower adjacent values respectively. They are the largest/smallest observed productivity whose distance from the top/bottom quartile are not more that 1.5 times the interquartile range. The outline values are observations on the original distribution that lie outside the adjacent values (outliers).

Figure 2 shows how the interquartile range has narrowed from 1980 to 1985, the top quartile decreases and the bottom one increases. Starting at the end of the 80s, the interquartile range spread up due to a decrease of the bottom quartile. The lower adjacent value at the end of the sample is as large as in 1980. The median is always under one, indicating that the distribution is asymmetric. It oscillates over the whole period, to end up at a lower level than in 1980.

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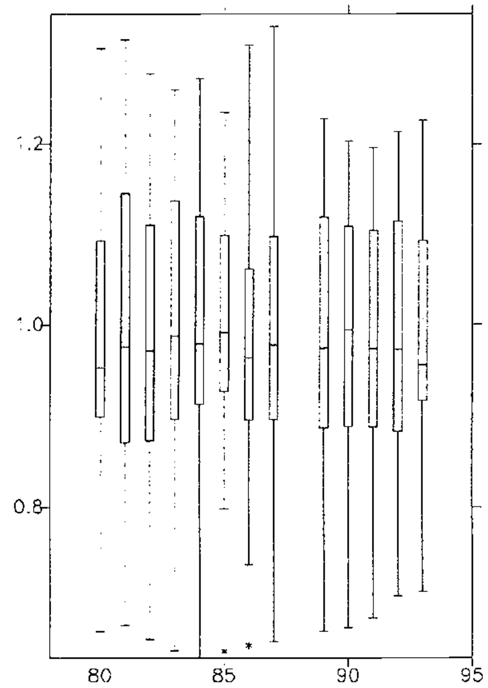
dynamics.

[12] We will come back to this idea when analyzing the quartiles series in the context of the model in section II.4.

The outlier in 1985 is Galicia, which remains on the bottom of the distribution all along the sample period

Figure 2: Tukey Boxplots.
Relative Labor Productivity Across 17 Spanish Regions



I.3. A first approximation to the labor productivity dynamics

The behavior of the cross-section distribution refers not only to changes in the shape but also to the intra-distribution mobility. The dynamics of each region's relative position is a crucial component of the notion of convergence that the growth literature is concerned with. Figure 3 is a first approximation to these dynamics.[13] It gives information on the dynamics of labor productivity across regions and over time. It ranks the regions according to their relative productivity in the first year of the sample and shows the evolution of the ranking over time. Each line (cross-profile line) represents, for a single year, the relative productivity of the Spanish regions ordered according to the initial ranking. Consequently, for the initial year the line is monotonically increasing.

The slope of these lines is a measure of inequality: the larger is the productivity

[13] The cross-profile graphic was first used by Dolado, Gonzalez-Páramo and Roldán (1994).

inequality the steeper these cross-profile lines are (shape dynamics). In the hypothetical case of all the regions having the same productivity levels all the observations should be over the horizontal, and Z_{it} would be one for every region. We have added a horizontal line (zero slope) as a reference. The evolution of the slope over time gives an idea of the convergence/divergence process. If the profile lines evolve tending to the horizontal this indicates that some homogenization has taken place (convergence). When a S shape appears, it indicates polarization (clubs formation).

The peaks on the profile lines are indicators of changes on the ranking (i.e. intra-distribution mobility). When a region overtakes another one, modifying the rank, it generates a segment with negative slope on the future years line. If on the contrary, there is persistence the lines will keep a monotone positive slope over time. A profile line crossing the horizontal is indicating that regions under the national average become more productive than the average, and vice-verse; this may be understood as evidence of convergence, in the sense of no persistence of the inequalities.

In Figure 3 the lines correspond to 1980, 1985, 1991 and 1993. For the regions with labor productivity relatively low, the slope of those lines remains unchanged. It is remarkable that the least productive regions do not approach the aggregate. For those regions close to the average the slope has decreased and the mobility is remarkable in the mid 80's; in particular for Murcia, Asturias, Valence Region, Cantabria, Aragon and La Rioja. The regions with initial productivity higher than the average tend to approach the average (i.e. lower slope in this segment of the line). Additionally at the beginning of the 80's, there is some mobility among those efficient regions: Navarre looses positions in the ranking and Baleares improves its position. During the second half of the 80's they recover the initial ranking.

Figure 3. Cross-profile dynamics
Relative Labor Productivity Across 17 Spanish Regions

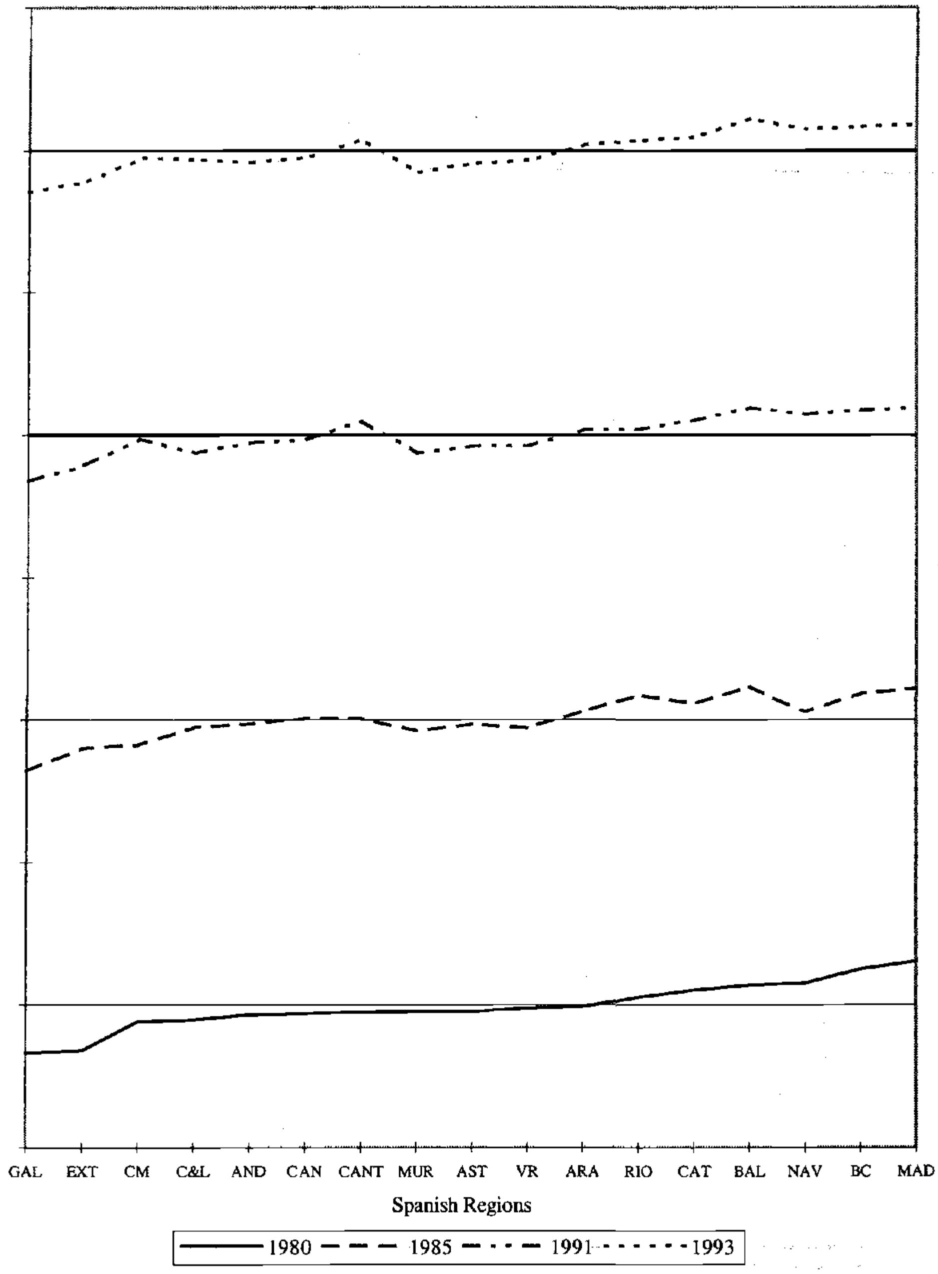


Table 1 shows in the first column the slopes of the profile lines for the whole sample period. The second column gives, on average, the relative productivity of a region with respect to another one, which placed four positions lower in the rank. Denote x the slope of the cross-profile lines of our variable Z_{it}, expressed now in logs, e^x is on average, the relative productivity of one economy with respect its precedent in the rank. e^{4x} tells how much larger is the productivity of a region with respect to another one that is four positions below.[14]

Table 1. Cross-profile dynamics.
Relative Labor Productivity Across 17 Spanish Regions (1980-93)

Years	Slope (x)	e^{4x}
1980	0.0338	1.15
1981	0.0362	1.16
1982	0.0354	1.15
1983	0.0366	1.16
1984	0.0331	1.14
1985	0.0291	1.12
1986	0.0308	1.13
1987	0.0315	1.15
1988	0.0283	1.12
1989	0.0282	1.12
1990	0.0273	1.12
1991	0.0260	1.11
1992	0.0262	1.11
1993	0.0256	1.11

I.4. Modeling the distribution dynamics

Making progress in the analysis requires a formal statistical structure to model the dynamics of the distribution as realizations of the random element in the space of distributions. Those models have been used in the recent convergence literature. Following Quah (1993, 1996, 1997), let $\{\lambda_t\}$ be the sequence of probability measures associated with the cross-section distribution. The simplest probability model is as follows:

$$\lambda_t = T^*(\lambda_{t-1}, \mu_t), \qquad [2]$$

where a stochastic difference equation describes the evolution of the sequence of distributions. T^* maps probability measures plus a disturbance term into probability measures and hence, it encodes information on how economies transit from t to $t+1$ and has to be estimated from the data. T^* can be approximated by discretizing the state-space of possible values of productivity (state). The discretization defines a grid that can be thought of as an estimator of the initial unconditional probability distribution λ_t. In this case T^* is simply a transition probability matrix and λ_t is a probability vector, i.e. the difference equation represents a Markov process. It is well known that the arbitrary discretization, may affect characteristics of the ergodic distribution and as well as the Markov property. Nevertheless, retaining the original continuous state-space of

[14] x is simply the OLS slope for the 14 cross-profile lines, one each year.

productivity levels is not possible given the sample limitations (seventeen cross-section observations)[15]. Consequently, we are sticking to the discrete model, taking special care to offer only robust results after exploring different possible discretizations.

The transition probability matrix encodes the relevant information on turnover in the distribution. Under some regularity conditions, the sequence of powers of this matrix converges to a matrix whose rows (all of them identical) are the ergodic distribution, which allows us to talk about steady state. In other words, if the system continues evolving with no structural change, it should eventually arrive to a long run steady-state. Convergence would be identified by a situation in which the cross-section distribution achieved in the long run is uni-modal and degenerated.

Alternatively, by fixing the probability vectors to be uniform and identical for every time point, $\lambda_t=\lambda$, we define a time-variant grid (quartiles), and associated to that, a sequence of fractiles transition probability matrices. The change in the grid describes the evolution of the cross-section distribution for one period to the next one; this allows us to study whether convergence is taking place and to characterize the long-run as the sequence of quartiles degenerating to the mean.

II.4.a.Time-invariant matrices, stationary model

We discretize the space of possible values of labor productivity into four states, such that the grid divides the total observed sample into categories for providing a uniform distribution. Consequently, the lengths of the defined states are different. These categories are very narrow around the value one, which corresponds to regions having a labor productivity around the aggregate, and wider for less productive regions. The first row of table 2 shows the upper limit of these states. The first column is the total number of transitions over the whole time sample, starting at each state. The rest of the table 2 presents the maximum-likelihood estimators of the time-invariant transition probability matrix for a single period and of the ergodic distribution (last row on the table). Each element of the matrix indicates the probability of transition from one state to another in one period. (h,g) entry is the probability that a region in state h transits to the state g. In other words, each row is a conditional probability vector. For instance, the first row of the

[15] For this continuos case T^* becomes a Stochastic Kernel (Stokey and Lucas (1989)) which is a complete description of transitions from a state into any other. It gives us information about both, exterior shape and intra-distribution dynamics through the sample period.

transition probability matrix gives the probabilities of transitions in one period from the first state to each one of the states. The main diagonal tells us about persistence, since it gives the probability of a region remaining where it is after one year. Persistence is higher for the low and high productivity group.

Table 2. Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-93

	Upper Limits			
(Nº)	**0.918**	**0.981**	**1.128**	**1.335**
52	0.90	0.10	0.00	0.00
51	0.10	0.76	0.14	0.00
52	0.00	0.11	0.81	0.08
49	0.00	0.00	0.10	0.90
Ergodic	0.248	0.244	0.290	0.218

The ergodic distribution, gives us the unconditional probability for a region to end up in a particular productivity range under the assumption that there is not a structural change and the system keeps evolving in the same fashion. We end up with a distribution that gives an approximately equal probability of reaching different states (although this probability is slightly higher for the average states).

Table 3 and Table 4 show the probability transition matrices for the sub-sample 1980-85 and 1985-93. During the first period there is less persistence.

Table 3. Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-85

	Upper Limits			
(Nº)	**0.923**	**0.980**	**1.138**	**1.321**
21	0.86	0.10	0.05	0.00
22	0.14	0.73	0.14	0.00
21	0.05	0.10	0.76	0.10
21	0.00	0.00	0.19	0.81

Table 4. Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1985-93

	Upper Limits			
(Nº)	**0.913**	**0.999**	**1.121**	**1.335**
36	0.86	0.14	0.00	0.00
33	0.15	0.79	0.06	0.00
35	0.00	0.09	0.86	0.06
32	0.00	0.00	0.06	0.94

I.4.b.Time-variant matrices, evolving model

The calculations above require time-invariant transition probabilities, which are not always reasonable over long periods in which, for example, some economic structural changes may happen.

We define a time-variant grid, i.e. the set of quartiles determines the sequence of cross-section distribution, hence, the change in the grid describes the evolution of the cross-section distribution for one period to the next one. This allows us to study whether convergence is taking place and to characterize the long-run as the sequence of quartiles degenerating to the mean. Associated to these grids there is a sequence of fractile transition probability matrices that shows the intra-distribution mobility.[16]

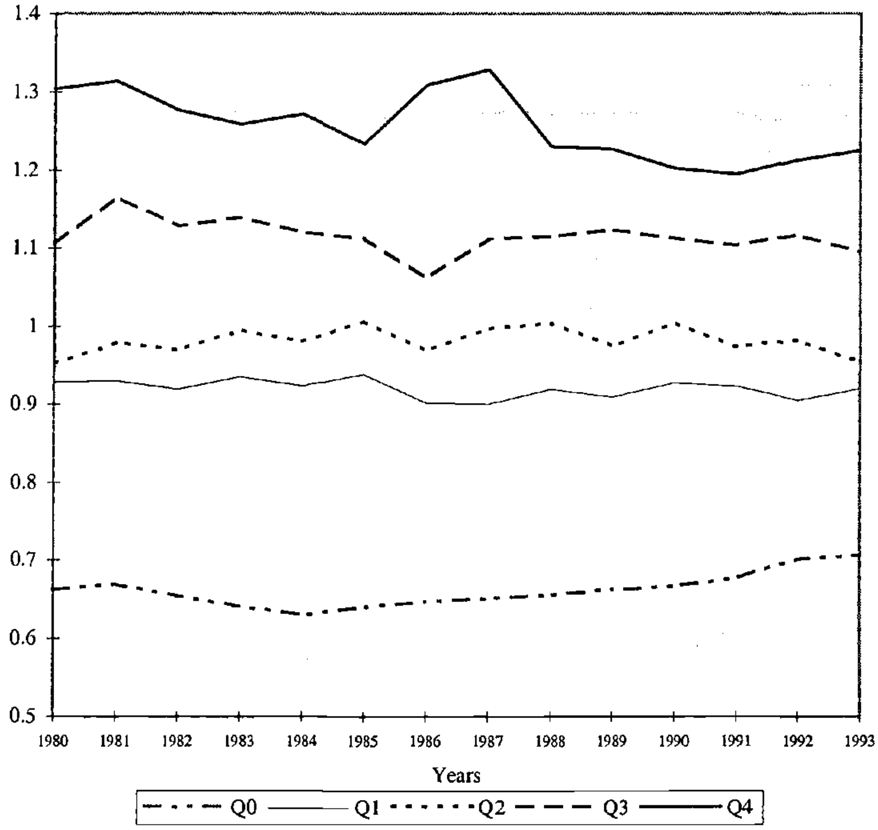
Figure 4 shows the sequence of percentiles (quartiles for a probability 0.25).[17] In other words the probability of being in a productivity interval is fixed to 0.25, consequently the interval limits will change over time.

The 25% of regions with the lowest productivity in 1980 fell in a range of 0.66 to 0.90 of the average. The upper limit of this interval (Q1) suffers some variation during the crises period 1980-85, but remains unchanged for the rest of the sample at approximately the 1980 level. The lower limit (Q0) deteriorates during the crisis and steadily recovers afterwards, to almost reach the 1980 situation. The distance from the national level oscillates around 40%. Second and third quartiles are very stable. The upper quartile slowly approaches the average (the peak corresponds to Baleares taking over Madrid).

[16] Results available upon request.

[17] In 1980 the Spanish regions are placed in the following intervals: Galicia, Extremadura, Castile & Leon and Castile-La Mancha in [Q0,Q1], Andalusia, Canary Islands, Cantabria and Murcia in [Q1,Q2], Aragon, La Rioja, Valence Region and Asturias in [Q2,Q3], and finally, Baleares, Cataluña, Navarre, Basque Country and Madrid in [Q3,Q4].

Figure 4. QUARTILES
Relative Labor Productivity Across 17 Spanish Regions (1980-93)



To characterize the long-run in the context of this model we should use time-series techniques (VAR) to test whether the sequence of quartiles tends to approach. The available sample 1980-93 is too short to extract any sensible conclusion.

I.5 Conclusions

The dynamics of observed labor productivity across Spanish regions (1980-93) shows a considerable persistence mainly during 1985-93. The least productive regions do not improve positions, the more productive regions very slightly approach the national aggregate during 1980-85.

II. The role of public investment

II.1 Introduction

The evolution of labor productivity during the period 1980-93 can be influenced by the distribution of the productive factors, in particular by public capital. In this sense public investment can affect the convergence process via public capital. Our main goal in this paper is to see whether public investment and its allocation have had an effect on the productivity convergence process.

We estimate a regional production function in which public capital is included as one of the arguments. We use this estimation to simulate virtual series of productivity under alternative public investment scenarios. The way of proceeding is the following: we generate alternative stocks of public capital, different from the observed ones (*virtual public capital)* by re-distributing the national public investment. Then, we recover labor productivity under the new public investment distribution *(virtual labor productivity)* using the estimated production function. The comparison of the dynamics of virtual productivity with the one of observed productivity will give us information on the impact of public investment policy on convergence.

This second part of the paper is organized as follows. Section II.2 estimates the production function. Section II.3 simulates the virtual productivity under different scenarios for public investment and analyzes the dynamics of that virtual productivity.

II.2. Estimating a regional production function

There is a large empirical literature on regional production functions. Our aim here is to estimate a production function that we can use to simulate virtual productivity series under different public investment scenarios.

We estimate an aggregate regional Cobb-Douglas production function,

$$Y_{it}=A_{it}\,K_{it}^{\alpha}\,L_{it}^{\beta}\,H_{it}^{\gamma}\,, \qquad [3]$$

where i indexes regions and t indexes periods of time. Y_{it}, K_{it}, and L_{it} are output, capital stock and employment of region i at time t respectively and H_{it} is human capital. We also assume that

$$A_{it} = \exp\left(\alpha_i + \delta t - \vartheta_1 LnCU_t + \vartheta_2 + LnU_{it}\right). \qquad [4]$$

In other words, the efficiency of the private factors depends on a regional specific factor α_i, an aggregate business cycle proxy CU_t, a regional business cycle proxy U_{it}, technical progress (a trend) and on transport cost T_{it}. The latter is modeled as follows:

$$T_{it} = \left(\frac{PC_{it}}{SUP_i^{\eta_1} \; POP_{it}^{\eta_2} \; PD_i^{\eta_3} \; ALT_i^{\eta_4}} \right)^{-\tau}, \qquad [5]$$

where $\sum_{i=1}^{4} \eta_i = 1$. PC_{it} is the stock of public capital, SUP_{it} is the size in km^2, POP_{it} is population. PD_i is a proxy for the population dispersion, and ALT_i is a proxy for the orography of region i.

Taking logs:

$$LnT_{it} = -\tau LnPC_{it} + \tau\eta_1 \, LnSUP_i + \tau\eta_2 LnPOP_{it} + \tau\eta_3 LnPD_i + \tau\eta_4 LnALT_i \; . \qquad [6]$$

The production function can be written (substituting [4] and [5] into [6]) in terms of labor productivity as follows:

$$\begin{aligned} Ln\left[Y_{it} / L_{it}\right] = \; & \alpha_i + \delta t + \alpha \, Ln\left[K_{it} / L_{it}\right] + \gamma Ln\left[H_{it} / L_{it}\right] + \phi Ln\left[PC_{it} / L_{it}\right] + \\ & + \left[\alpha + \beta + \gamma + \phi - 1\right] LnL_{it} + \vartheta_1 Ln\, CU_t + \vartheta_2 Ln\, U_{it} + \vartheta_3 LnSUP_i + \\ & + \vartheta_4 Ln\, POB_{it} + \vartheta_5 Ln\, PD_i + \vartheta_6 Ln\, ALT_i + \mu_{it} \end{aligned} \qquad [7]$$

where

$$\begin{aligned} \phi &= \varepsilon\tau \\ \vartheta_3 &= -\varepsilon\tau\eta_1 \\ \vartheta_4 &= -\varepsilon\tau\eta_2 \\ \vartheta_5 &= -\varepsilon\tau\eta_3 \\ \vartheta_6 &= -\varepsilon\tau\eta_4 \end{aligned}$$

We estimate equation [7] for the 17 Spanish regions as defined above, during the period 1980-93.

The data on output, employment and private capital are those of the private productive sector, i.e. Y_{it}, K_{it} and L_{it} are respectively the output, capital stock and employment from the private productive sector of region i at time t.[18] Human capital (H_{it}) is measured as the number of workers in the region with at least some university degree (equivalent to bachelor). PC_{it} is measured as the stock of capital on infrastructure.[19] As

18 Most of the data are drawn from the BD.MORES and the INE publications (see data appendix).

19 From both, public and private sector. During 1980-93 the investment in infrastructure carried out by para-state organizations was around a 20% of the total.

the proxy for the population dispersion of each region we use the number of self-contained districts (urban and rural areas) in that region, and we proxy the orography features of each region (except when explicitly indicated) by the standard deviation of the altitude of that region. α_i includes the unobservable region-specific characteristics of the production function (or simply the region-specific characteristics omitted from the specification). CU_t is an aggregate (national) measure of productive capacity utilization and U_{it} is unemployment rate for region *i* at time *t*.[20]

The main peculiarity of our production function specification is that it includes among the regressors some region-specific factors that are observable (*POP, SUP, ALT* and *PD*). Most of the literature includes those features into α_i, which normally is eliminated by using fixed affect techniques on the estimation.[21]

In estimating [7] we do not use fixed regional effects methods, in an attempt to retain information from the cross-section variation. Often fixed effects are forced by the need of taking first differences in order to correct non stationarity. This is not our case, when applying the Bhargava, Fanzini and Narendranathan (1982) modified Durbin-Watson test we can reject the hypothesis that the residual follow a random walk.[22] This modified Durbin-Watson statistic takes value 1.27 which corresponds to a correlation coefficient around 0.45.

We assume the following error term specification: $\varepsilon_{it} = \mu_{it} + \alpha_i$, where μ_{it} are *iid* errors and α_i is the unobservable region specific component (individual effect). We do not include any time specific component since our variables CU_t and U_{it} are already controlling for business cycle effects.

We tested and accepted the following hypothesis: $\alpha = \vartheta_1$, and $-\phi + \vartheta_3 + \vartheta_4 + \vartheta_5 + \vartheta_6 = 0$. Concerning the CRTS property, we understand that whether it holds or not is an empirical issue, consequently we do not impose it on the estimation. Estimation is carried out using the Generalized Method of Moments (GMM), Hansen (1982), to guaranty consistent and efficient estimates.

There are several potential sources of endogeneity (correlation between the regressors and the error terms) which may call for instrumental variable methods. A first one is that observed capital, employment and output may be jointly determined. The

20 *CU* is not available, at a regional level, in the BD.MORES database and we use the national one.
21 Fixed effect techniques imply taking some sort of differences.
22 Although, there is some auto-correlation. We account for it when estimating.

Hausman test for this endogeneity hypothesis indicates that we should instrument both private capital and employment.

Also, it has been argued in the literature that public capital may be correlated with the region-specific components. If it is correlated with the observed region specific component we face a problem of multicollinearity. If public capital is correlated with the individual effect (α_i), we need to instrument public capital. A Hausman test of endogeneity suggests, in this case, the need of instrumenting public capital. To deal with this issue, we have constructed several instruments for each region based on measures of the public capital of the neighboring regions.

Estimation results are shown on Table 5. Population is not significant, (column (1)) this is due to a problem of multicolinearity between population and employment.[23] Also, the trend appears not significant, which is reasonable since we cannot reject increasing returns to scale. In column (5), before applying GMM, the data were transformed taking cuasi-differences in a Cochrane-Orcutt fashion, to correct autocorrelation.

The estimated coefficient of public capital is quite robust, it takes values from 0.10 and 0.13. The estimated coefficients of private, human and public capital are significant and have the expected sign.[24] Besides that, the implied contributions of capital and labor to aggregate output are in accordance with the factor income shares suggested in national income accounts. And they are quite stable for the different specifications. PD_{it} and SUP_i present the expected sign, although the deviation of the altitude has a positive sign, which may sound counter-intuitive.[25] The estimation in column (4) has been performed using a different measure of orography (log (deviation of the altitude)/log (mean of the altitude)). In this case the positive sing means that the higher the average altitude for a region the higher the transport cost (lower the labor productivity) and the magnitude of the effect is qualify by the standard deviation of that region's altitude with respect to the rest of the regions.

[23] Table I in the Annex presents the sample correlations among the explanatory variables.
[24] Except for human capital in column (5), which is not significant.
[25] More than in the individual contribution of the regional-specific factors we are interested in their global contribution. See column (6) Table IV in the Annex.

Table 5. Production Function Estimation
17 Spanish Regions 1980-93

	(1)	(2)	(3)	(4)(*)	(5)
Constant	4.453 (8.440)	4.672 (8.311)	4.658 (8.173)	5.225 (9.963)	3.787 (4.357)
K	0.244 (3.552)	0.252 (3.784)	0.251 (3.700)	0.218 (3.114)	0.388 (3.779)
L	0.2069 (4.337)	0.145 (11.313)	0.145 (10.469)	0.137 (9.301)	0.137 (8.180)
PC	**0.130** **(4.457)**	**0.115** **(4.737)**	**0.108** **(4.422)**	**0.104** **(3.162)**	**0.099** **(2.895)**
H	0.274 (4.732)	0.287 (4.923)	0.249 (4.992)	0.259 (5.482)	0.016 (0.294)
POP	-0.055 (-1.712)	-	-	-	-
SUP	-0.095 (-9.412)	-0.097 (-10.324)	-0.099 (-10.157)	-0.096 (-10.330)	-0.110 (-8.100)
PD	-0.0773 (-7.878)	-0.069 (-8.595)	-0.072 (-8.748)	-0.072 (-7.964)	-0.077 (-7.313)
ALT	0.093 (2.556)	0.052 (2.133)	0.062 (2.673)	0.064 (2.135)	0.088 (2.624)
U	-0.124 (-4.074)	-0.143 (-4.719)	-0.137 (-4.541)	-0.129 (-4.630)	-0.055 (-2.381)
Trend	-0.004 (-1.219)	-0.004 (-1.152)	-	-	-
Nº Obs	204	204	204	204	187
R^2	0.720	0.722	0.726	0.718	0.516
Se^2	0.096	0.096	0.095	0.096	0.044

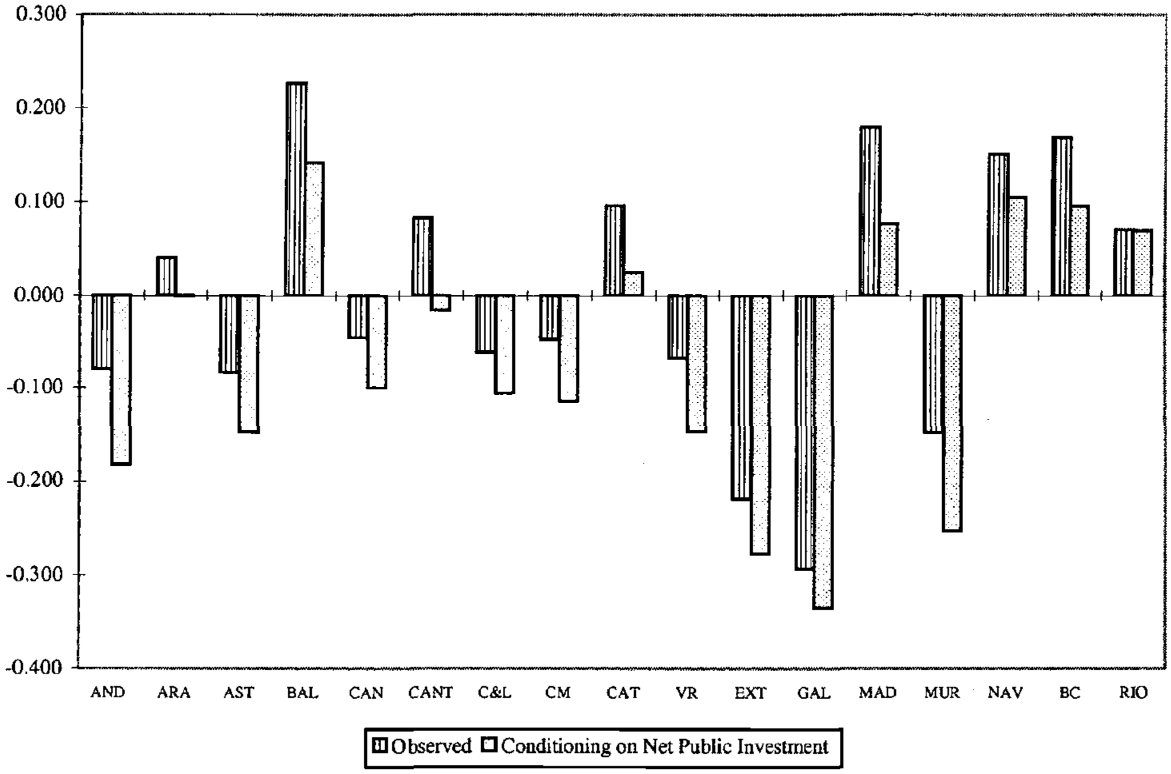
Dependent Variable: Regional Labor Productivity. GMM estimators (Hansen (1982)). t-Student in brackets. Instruments: one and two lags of private capital, one lag of employment and public capital and a measure of the neighboring regions' PC. (*) ALT refers to log(deviation of the altitude)/log (mean of the altitude).

II.3.a.Conditioning on Public Investment.

The first exercise consists of studying the distribution dynamics of labor productivity-disparities which cannot be explained by public capital investment flows, in the periods 1980-93. We assume that the net public investment has been zero. This gives us a series of virtual public capital which remains constant at the level 1980 (beginning of the sample). We use it to compute a series of labor productivity where the public investment flows have been conditioned out.[26]

The evidence from studying the virtual productivity in this scenario seems to indicate that public investment flows have had a remarkable effect. Figure 5 shows deviations with respect to the observed national aggregate of both, virtual (conditional) and observed productivity in 1993.[27]

Figure 5
Relative Labor Productivity: Observed and Virtual
Regional Distance to the Observed Aggregate. 1993



All the regions have benefited from public investment, although in an asymmetric way. Regional public investment has reduced the distance between the less productive regions and the observed aggregate, but it has increased in a larger magnitude the

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26 This computation is carried out writing the estimated production function [7] as: $y_{it}^{o} = z_{it}^{o} + \hat{\phi}\, pc_{it}^{o} + error$, where y_{it}^{o} is the observed labor productivity (in logs), pc_{it}^{o} the observed public capital per worker (in logs), and z_{it}^{o} the estimated contribution of the rest of regressors. Then, the virtual labor productivity is: $y_{it}^{v} = y_{it}^{o} + \hat{\phi}\left(pc_{it}^{v} - pc_{it}^{o}\right)$, where v denotes virtual. Notice that by doing that, we assume that K7L and H/L are similar in the observed and virtual economy. $\hat{\phi}$ has been taken as 0.12.

27 Similar figures are available upon request for every year of the sample.

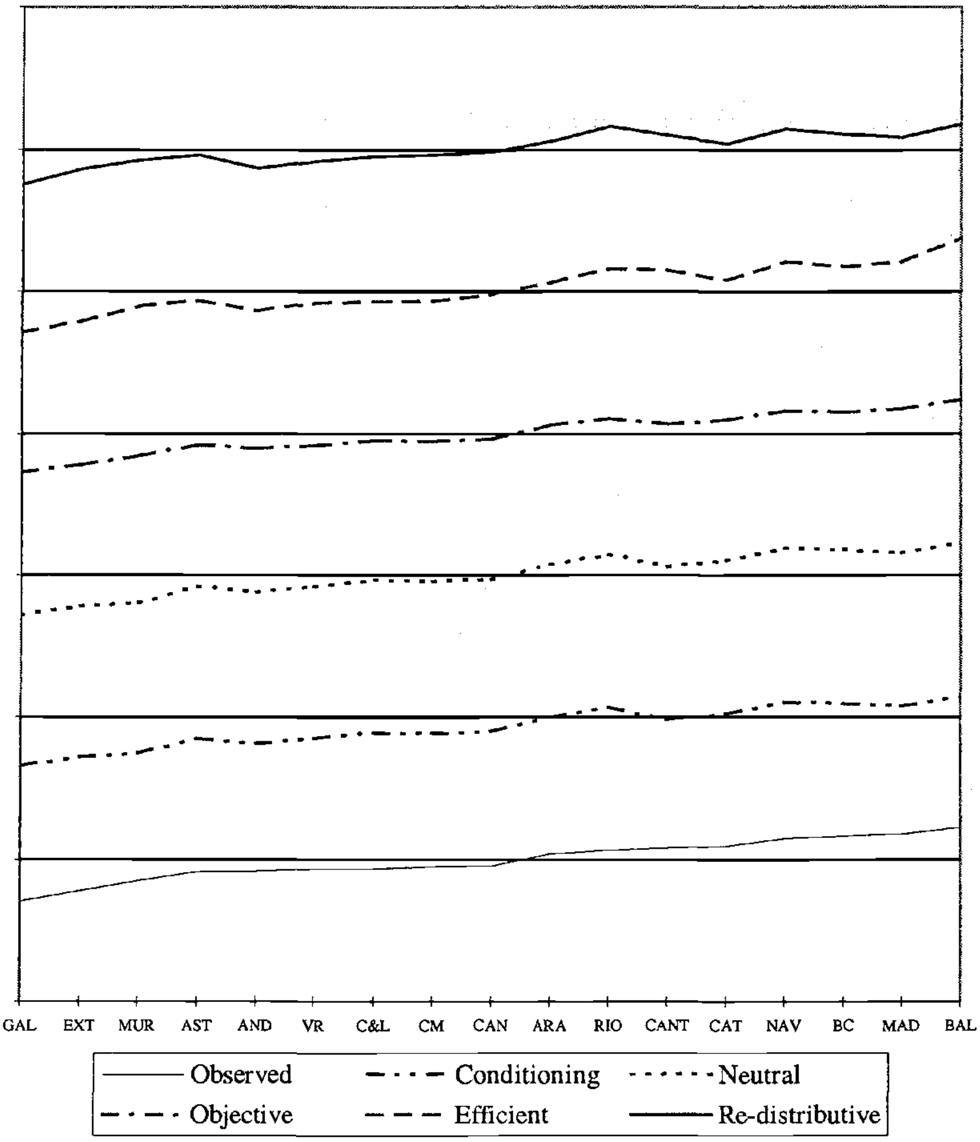
distance of the more productive regions. For instance, due to public investment Basque Country and Madrid have duplicated their deviation from the aggregate in 1993 and Catalonia has more than triplicated it. Aragon and Cantabria in absence of public investment would have had a productivity below aggregate in 1993. Public investment has been neutral for La Rioja.[28]

Figure 6 is a way to look at the situation in 1993 under the different scenarios and to compare that situation with the observed one. It is a cross-profile graphic, where the first line ranks the regions according to their observed relative productivity in 1993. Each one of the other cross-profile lines represents, for alternative scenarios in 1993, the virtual relative productivity of Spanish regions ordered according the observed ranking in the same year.

[28] La Rioja did not receive any public investment (investment in infrastructures) during the sample period.

[28] La Rioja will be better off in all the considered scenarios.

Figure 6: Cross-Profile. 17 Spanish Regions
Observed and Virtual Labor Productivity in 1993. Alternarive Scenarios



The second line corresponds to the current scenario, where public investment has been conditioned out. Among the regions which in 1993 are less productive than average those closer to the aggregate present a observed slope smaller than the virtual one, indicating that public investment has contributed to their convergence towards the aggregate. And the least productive ones have a similar (slightly better) relative position with and without public investment. While the more productive regions (except La Rioja) have benefited from investment and have moved (more) apart from the aggregate.[29]

[29] La Rioja will be better off in all the considered scenarios.

Tables 6 to 8 show the conditional time-invariant transition matrices in absence of public investement.[30] We find that after conditioning *(virtual productivity)* there is persistence for the least productive regions but the more productive have a higher probability of moving downwards.

Summarizing, public investment has helped the lower-middle class, i.e. those regions which are less productive than the aggregate but close to it to converge. Although, after conditioning out investment, the least efficient regions are in a similar position but the more efficient ones are worse off, which means that in the short-run public investment has contributed to increase the deviation of the more productive regions.

Table 6. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-93
Conditioning on Net Public Investment

	Upper Limits			
(N°)	**0.865**	**0.969**	**1.100**	**1.317**
50	0.92	0.08	0.00	0.00
53	0.11	0.77	0.11	0.00
50	0.00	0.14	0.78	0.00
51	0.00	0.00	0.14	0.86
Ergodic	0.383	0.271	0.219	0.128

Table 7. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-85
Conditioning on Net public investment

	Upper Limits			
(N°)	**0.900**	**0.978**	**1.141**	**1.317**
20	0.95	0.05	0.00	0.00
23	0.13	0.70	0.17	0.00
21	0.00	0.19	0.71	0.10
21	0.00	0.00	0.19	0.81

Table 8. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1985-93
Conditioning on Net public investment

	Upper Limits			
(N°)	**0.854**	**0.967**	**1.087**	**1.281**
33	0.88	0.12	0.00	0.00
36	0.19	0.78	0.03	0.00
34	0.00	0.06	0.91	0.03
33	0.00	0.00	0.09	0.91

[30] Dividing the sample in 1980-85 and 1985-93, is specially important when talking of public investment. From 1985 public investment in Spain has increased drastically. See Figure 1.A. in the annex. Both, national and European founds contributed to this increase. Spain joined the EU in 1986 and nine out of the 17 regions considered in the sample receive European Structural Founds.

II.3.b. Public Investment re-allocation

In what follows we investigate whether given the aggregate amount of investment, its allocation across regions matters in terms of convergence. We define four different allocation scenarios, compute a series of virtual productivity in each one of them and analyze their dynamics. Comparing it with the observed dynamics gives us an idea of effects of the allocation of public investment.[31]

Scenario 1: 'neutral' public investment allocation

The strategy here is to re-allocate the aggregate public investment in such a way that the regional relative public capital over the whole sample is the same as in 1980. In other terms, our policy maintains as constant the relative capital of the regions over the whole sample. We call this scenario 'neutral' since it does not affect the relative public capital of the regions.

Figure 7.
Relative Labor Productivity: Observed and Virtual
Regional Distance to the Observed Aggregate. 1993

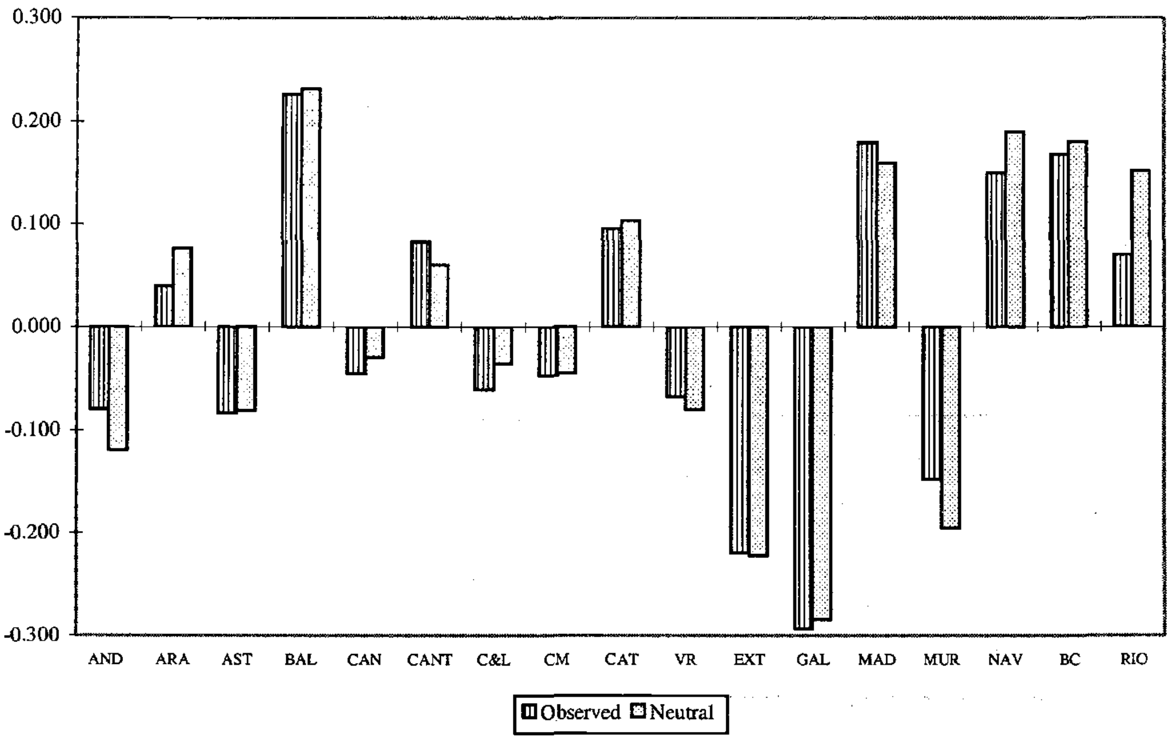


Figure 7 suggests that there are small differences between the virtual and observed productivity in 1993 relative to the observed aggregate. As it can be seen in this figure

[31] Conditioning out the European Structural Founds is on the agenda.

some regions such as Andalusia and Murcia would have received less public investment under this neutral scenario, and consequently, they would have a lower labor productivity at the end of the sample, being further away from the aggregate. On the other hand, La Rioja, Aragon and Navarre would have received more public investment and so would present a higher positive deviation as regards their labor productivity in 1993. Notice that in general, La Rioja's virtual productivity will be over the observed one for each scenario and Andalusia's virtual productivity will be, on the contrary, under it.

Distribution dynamics analysis of the virtual productivity in this scenario shows similar picture as for the observed productivity. There are small differences between Tables 9 to 11 and Tables 6 to 8, which reflects the just mentioned changes in the regions' relative position. The same conclusions can be drawn from Figure 6. It seems that either, the investment allocation has little effect on the relative performance of Spanish regions in terms of labor productivity, or the policy followed during the period 1980-93 has not substantially changed the relative public capital of the regions with respect to that in 1980.

Table 9. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-93
Neutral

	Upper Limits			
(Nº)	**0.906**	**0.986**	**1.149**	**1.319**
52	0.90	0.10	0.00	0.00
51	0.10	0.76	0.14	0.06
53	0.00	0.09	0.83	0.08
48	0.00	0.00	0.08	0.92
Ergodic	0.213	0.219	0.304	0.275

Table10. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-85
Neutral

	Upper Limits			
(Nº)	**0.914**	**0.981**	**1.151**	**1.319**
21	0.90	0.10	0.00	0.00
22	0.09	0.73	0.18	0.00
21	0.05	0.10	0.76	0.10
21	0.00	0.00	0.19	0.81

Table 11. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions First Order Transition Matrix. Time Stationary. 1985-93
Neutral

	Upper Limits			
(Nº)	**0.903**	**1.007**	**1.149**	**1.319**
35	0.86	0.14	0.00	0.00
34	0.18	0.79	0.03	0.00
36	0.00	0.03	0.92	0.06
31	0.00	0.00	0.03	0.97

Scenario 2: 'objective' public investment allocation

There are several factors due to which the government may need to invest more in a region than in another; among them: altitude, orography, population, population dispersion and size (Km^2), call these factors 'objective factors'. In this scenario we take them into account in defining the investment re-allocation across regions. Dabán and Lamo (1998) present some indicators of relative (regional with respect to the aggregate) public capital which account for differences in the above mentioned factors. We take here one of those indicators and use the weights that, orography, population, population dispersion and size (Km^2) have in the indicator to re-allocate public investment. Let X_{it} be that indicator:

$$X_{it} = \left(\frac{PC_{it}}{PC_{nt}}\right)\left(\frac{SUP_n}{SUP_i}\right)^{\alpha}\left(\frac{POP_{nt}}{POP_{it}}\right)^{\beta}\left(\frac{PD_n}{DP_i}\right)^{\gamma}\left(\frac{ALT_n}{ALT_i}\right)^{\delta}, \qquad [9]$$

n indices the country, i the region and t the time periods.[32]

By taking logs in [9] we get:

$$Ln[X_{it}] = Ln\left(\frac{PC_{it}}{PC_{nt}}\right) + \alpha\, Ln\left(\frac{SUP_n}{SUP_i}\right) + \beta\, Ln\left(\frac{POP_{nt}}{POP_{it}}\right) + \gamma\, Ln\left(\frac{PD_n}{PD_i}\right) + \delta\, Ln\left(\frac{ALT_n}{ALT_i}\right) \qquad [10]$$

Then we can estimate:

$$Ln\left(\frac{PC_{it}}{PC_{nt}}\right) = \alpha\, Ln\left(\frac{SUP_i}{SUP_n}\right) + \beta\, Ln\left(\frac{POP_{it}}{POP_{nt}}\right) + \gamma\, Ln\left(\frac{PD_i}{PD_n}\right) + \delta\, Ln\left(\frac{ALT_i}{ALT_n}\right) + \zeta_{it} \qquad [11]$$

Notice that:

$$X_{it} = e^{\zeta_{it}}. \qquad [12]$$

[32] Variable definitions as above.

We are interested on the residuals of equation [11]. Our index will include the part of relative public capital that is orthogonal to population, Km^2, population dispersion and orography. In other terms, the indicator measures relative public capital discounting for differences in those 'objective' factors.

The estimated parameters are: 0.161(α), 0.679(β), 0.093(γ) and 0.067(δ), all of them significant. As mentioned above, we use these estimators to compute a virtual net public investment $\left(NI_{it}^{v}\right)$,

$$NI_{it}^{v} = NI_{nt}\left(\frac{SUP_i}{SUP_n}\right)^{0.161}\left(\frac{POP_{nt}}{POP_{it}}\right)^{0.679}\left(\frac{PD_i}{PD_n}\right)^{0.093}\left(\frac{ALT_i}{ALT_n}\right)^{0.067} = NI_{nt}\cdot w_{it} \qquad [13]$$

where $\sum_{i=1}^{17} w_{it} = 1$ for each year and NI_{nt} represents the national net public investment.

Figure 8 again shows the deviations between the virtual and the observed regional productivity in 1993 under this objective scenario.[33] From Figure 8 we can conclude that there are not significant differences between the observed relative position of regions in terms of their labor productivity in 1993 and the virtual one under an 'objective' re-allocation of public investment.[34]

The distribution dynamics of the virtual productivity for the periods 1980-85 and 1985-93 (Tables 13 and 14 and Figure 6) show no remarkable difference to the dynamics of the observed productivity especially in the period 1985-93.

[33] Table X in the Annex shows the regional distribution of the virtual and observed public capital in 1993.
[34] Abstracting from La Rioja.

Figure 8
Relative Labor Productivity: Observed and Virtual Regional Distance to the Observed Aggregate. 1993

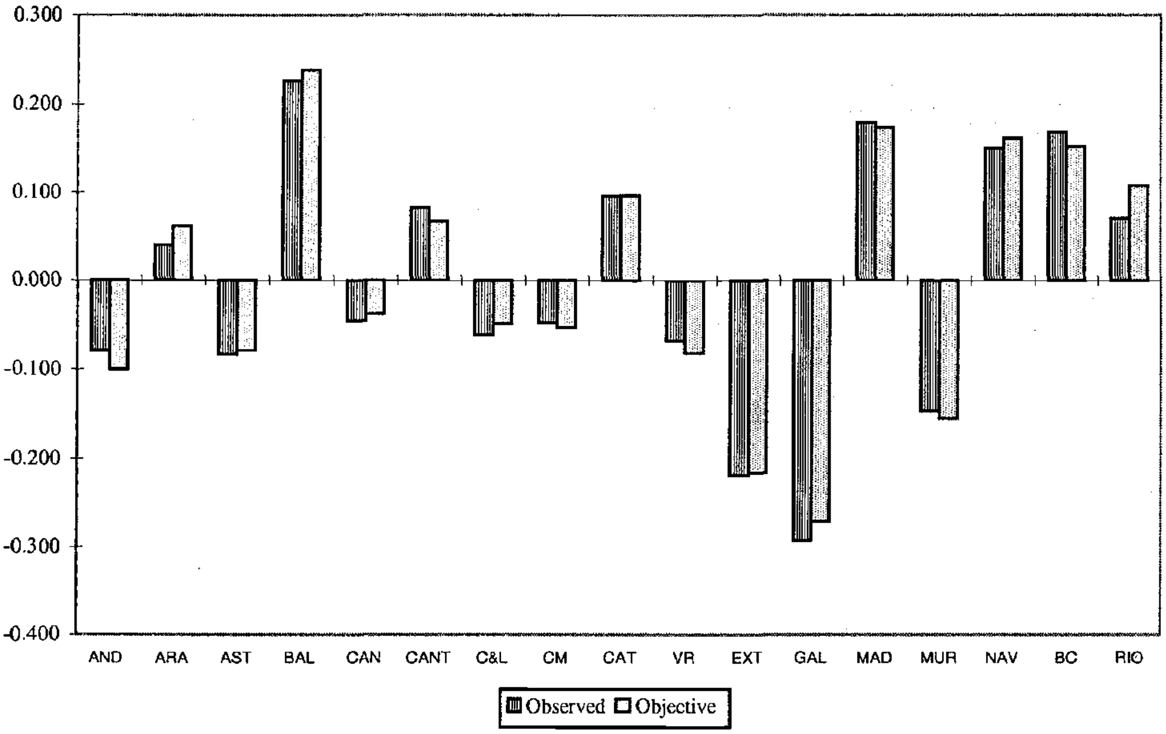


Table 12. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions First Order Transition Matrix. Time Stationary. 1980-93 Objective

	Upper Limits			
(N°)	**0.914**	**0.987**	**1.141**	**1.330**
52	0.88	0.12	0.00	0.00
51	0.12	0.75	0.14	0.00
52	0.00	0.10	0.87	0.04
49	0.00	0.00	0.06	0.94
Ergodic	0.235	0.230	0.329	0.206

Table 13. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions First Order Transition Matrix. Time Stationary. 1980-85 Objective

	Upper Limits			
(N°)	**0.928**	**0.983**	**1.149**	**1.324**
21	0.86	0.10	0.05	0.00
22	0.18	0.68	0.14	0.00
21	0.00	0.14	0.76	0.10
21	0.00	0.00	0.19	0.81

Table 14. Virtual Relative Labor Productivity Dynamics Across 17 Spanish Regions First Order Transition Matrix. Time Stationary. 1985-93 Objective

	Upper Limits			
(N°)	**0.911**	**1.007**	**1.131**	**1.333**
35	0.89	0.11	0.00	0.00
34	0.15	0.79	0.06	0.00
35	0.00	0.09	0.86	0.06
32	0.00	0.00	0.06	0.94

Scenario 3: 'efficiency' based public investment allocation

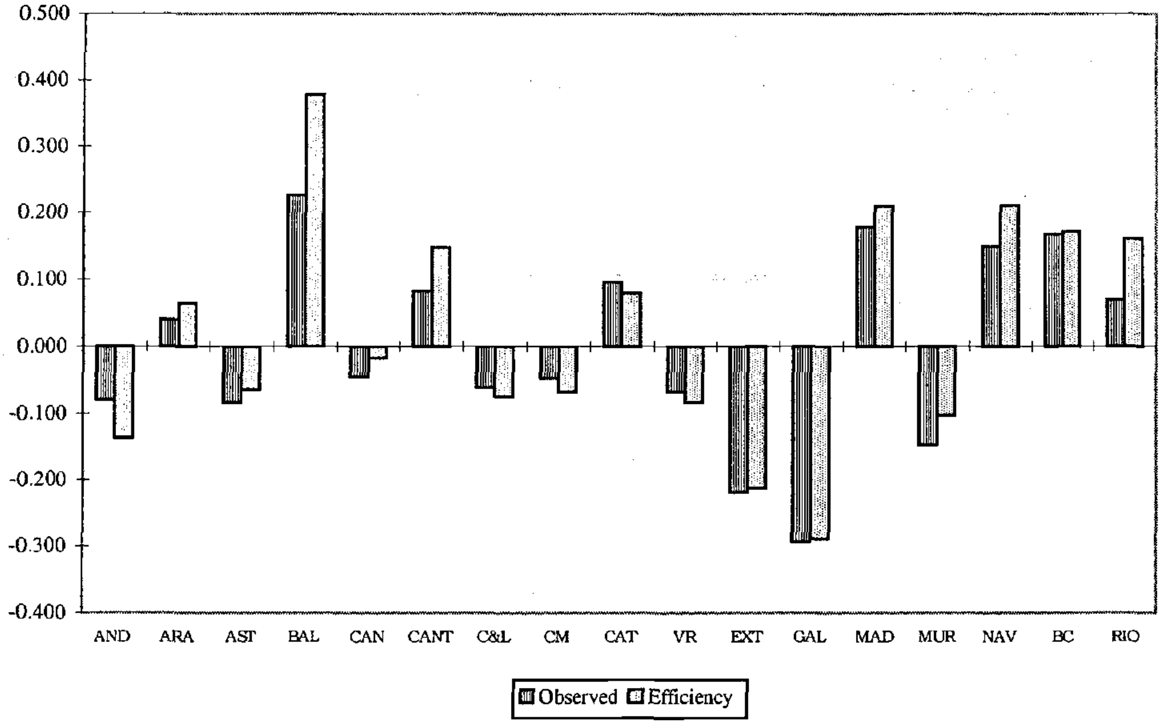
In this case, public investment would be allocated taking into account the expected returns of public capital, i.e. we consider an efficiency-based public investment allocation. Expected return of public capital is measured as the marginal productivity of public capital in a region, which can be calculated by using the estimated regional production function. Call *rpc* the gross return of public capital, then:

$$rpc_{it} = \hat{\phi} \cdot \left(Y_{it} / PC_{it} \right), \qquad [14]$$

Taking as given the situation in 1980 we re-allocate the observed aggregated/total net public investment for 1981, assigning more public investment to the regions with a higher *rpc*.[35] This gives us a cross-section of virtual public capital and virtual output for the 17 regions in 1981 and therefore a virtual gross return of public capital. To re-allocate the observed aggregate investment in 1982 we proceed in the same fashion but now we give more investment to the region with higher virtual (rather than observed) return of public capital in 1981. This reallocation procedure repeats every year recursively. Figure 9 shows the deviations of the virtual and the observed regional productivity with respect to the observed aggregate in 1993. The efficient allocation disadvantages Andalusia, the two Castiles and Catalonia.

[35] Table IX in the data Annex presents *rpc* for Spain and for the regions in 1980, 1985 and 1993. Notice for example that Madrid, Murcia, Baleares, Catalonia, Valencian Region and Andalusia have a *rpc* higher

Figure 9.
Relative Labor Productivity: Observed and Virtual
Regional Distance to the Aggregate. 1993



Inequality increases considerably under this scenario, see Table 1.A in the annex which present the cross-profile slopes for the alternative scenarios and Figure 2.A, also in the annex, which displays the standard deviation (σ-convergence) of labor productivity under the alternative scenarios. Consequently, the range of variation of relative labor productivity across regions has increased substantially, the upper limit of the highest quartile changes from 1.335 (observed) to 1.502 (virtual). Comparing the virtual and observed probability transition matrices is not straightforward due to this change in the quartile limits.

Scenario 4: 're-distributive' investment allocation

In this scenario, public investment allocation is designed taking into account only re-distributive goals. In other terms, we assume that regions with a lower relative labor productivity at the beginning of the sample would receive a higher amount of the national public investment. In particular, the amount of public investment assigned to a region would be proportional to the distance of that region's productivity to the highest

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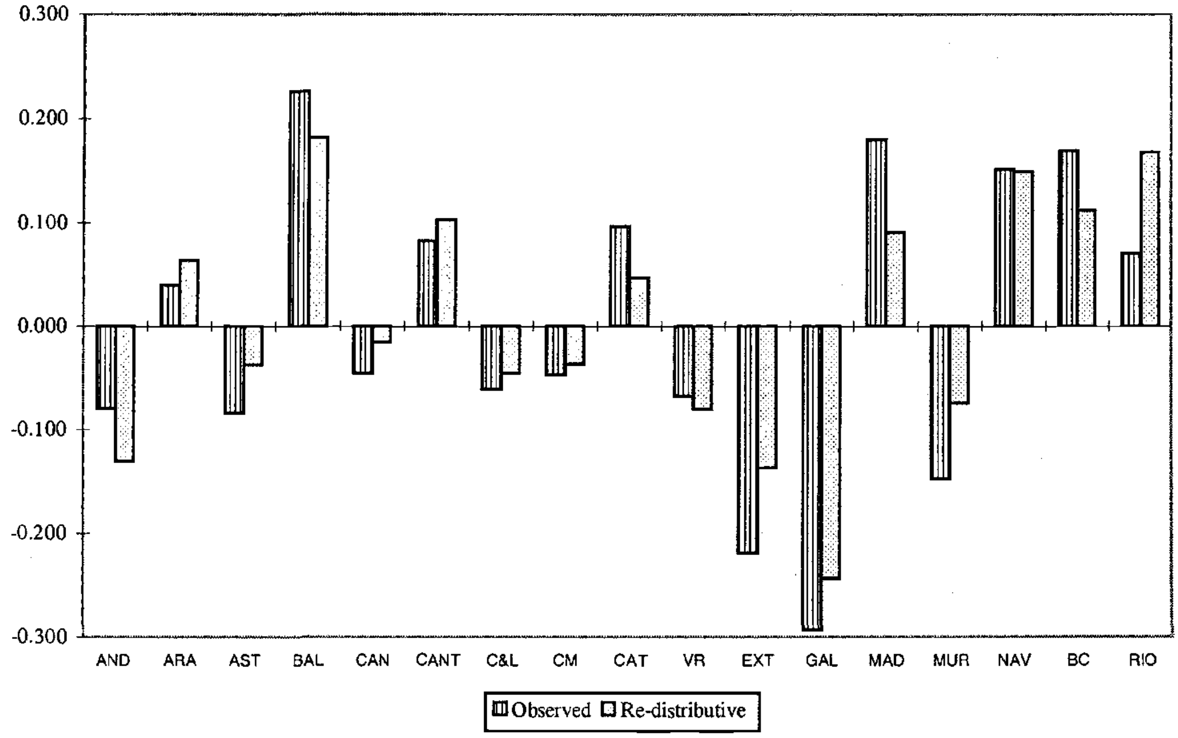
than the average (aggregate) in 1980.

productivity. The 1980's distribution remains unchanged. In 1981 the reallocation is done on the basis of the observed productivity in 1980, and for 1982 the re-allocation takes as basis the virtual productivity in 1981 and so on.[36]

Figure 10 presents the deviations between the virtual and the observed regional productivity in 1993. A purely re-distributive policy, on one hand would have reduced the advantage of the more productive regions except for La Rioja, Cantabria and Navarre. And on the other hand it would have favored the less productive regions as Galicia, Extremadura and Murcia, but it would have deteriorated the situation of Andalusia. The cross-profile line for this scenario (Figure 6) displays a small slope, it runs close to the horizontal apart from the peaks corresponding to Navarra and again Andalusia and La Rioja.

Figure 10.
Relative Labor Productivity: Observed and Virtual
Regional Distance to the Observed Aggregate. 1993



The analysis of the distribution dynamics shows a remarkable increase of mobility together with a decrease of the inequality. (See Tables 15 to 17, Table 1.A and Figure 2.A in the annex).

[36] This means that each year the region with the highest productivity that year did not receive any investment: Madrid (1980, 1981, 1988), Baleares (from 1983 to 1987, 1991 and 1993), Basque Country

Table 15. Virtual Relative Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-93.
Re-distributive Scenario

	Upper Limits			
(N°)	**0.916**	**1.002**	**1.134**	**1.317**
53	0.89	0.11	0.00	0.00
50	0.10	0.76	0.14	0.00
51	0.00	0.10	0.76	0.14
50	0.00	0.00	0.18	0.82
Ergodic	0.201	0.227	0.325	0.247

Table 16. Virtual Relative Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1980-85.
Re-distributive Scenario

	Upper Limits			
(N°)	**0.927**	**0.986**	**1.149**	**1.317**
21	0.86	0.14	0.00	0.00
23	0.17	0.61	0.22	0.00
20	0.00	0.10	0.80	0.10
21	0.00	0.00	0.19	0.81

Table 17. Virtual Relative Productivity Dynamics Across 17 Spanish Regions
First Order Transition Matrix. Time Stationary. 1985-93.
Re-distributive Scenario

	Upper Limits			
(N°)	**0.912**	**1.022**	**1.130**	**1.298**
36	0.86	0.14	0.00	0.00
33	0.15	0.76	0.09	0.00
34	0.00	0.09	0.76	0.15
33	0.00	0.00	0.18	0.82

III. Conclusions

This paper analyzed the dynamics of disparities in labor productivity across Spanish regions over the period 1980-93. Additionally, and in order to contribute to the design of regional policy, we studied the role of public investment in these dynamics.

The main findings of the paper are the following:

(i) The dynamics of observed labor productivity across Spanish regions (1980-93) shows a considerable persistence. The more productive regions slightly approach the national aggregate while the less productive ones do not improve positions. Besides that, regions in the middle of the distribution were quite mobile, mainly during 1980-85.

(1982 and 1990) and Navarre (1989 and 1992).

(ii) In the short-run public investment has contributed to increase the positive deviations of the most productive regions.

(iii) During the period 1980-93, the relative public capital of the regions has not changed substantially with respect to that in 1980.

(iii) The observed policy resembles an allocation criterion based on population, physical size, population dispersion and geographic features (orography).

(iv) To discern whether the two previous points are true or whether the public investment allocation simply does not affect convergence in the short run, we analyze two more scenarios: one is purely re-distributive and the other is based on efficiency. When the public investment allocation follows only an efficiency criterion the discrepancies across regions in terms of productivity are favored. Our re-distributive scenario generates a clear tendency toward convergence: a remarkable increase of mobility together with a decrease in inequality.

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Data Appendix

Output is real added value expressed in millions of pesetas 1980. It includes production of goods and services, at factor costs, produced in the region, by the private productive sectors: Agriculture (forestry and fishing), Industry (mining, manufacturing, construction and utilities) and private services (commerce, transport, and communications, banking and other private services). Housing rents are excluded. Source: BD.MORES of the Spanish Ministry of Finance.

Labor. Data on regional employment are the total working population of the private productive sector. Source BD.MORES database.

Private Capital. Figures refer to the net stock of capital in millions of pesetas 1980 held by the productive private sector. Thus, it does neither include the stock of residential buildings, nor the stock in productive infrastructures. Source: BD.MORES database.

Public Capital. Data refer to the net stock of productive infrastructure in millions of pesetas 1980. It comprises transportation networks, energy supply networks, water supply and sewage systems. They may be offered by government or government agencies, by regulated private or public enterprises, and by public or private organizations. Source: BD.MORES database.

Human Capital. It is measured as the number of workers in the region with at least some university degree (equivalent to bachelor). Source BD.MORES database.

Capacity Utilization. It is the proportion of available productive capacity that is currently utilized in the industry (survey-based measure) Source: Spanish Ministry of Industry.

Unemployment Rate. It measures the unemployed people as a percentage of labor force. Source: Labor Force Survey.

Extension is the size of each region in Km^2. Source: *Statistical Yearbook,* Spanish National Institute of Statistics.

Population is measured as millions of inhabitants in each region at the mid-year. Source: *Statistical Yearbook,* Spanish National Institute of Statistics.

Population Dispersion is measured as the number of self-contained districts (urban and rural areas). Source: *Nomenclator*, Spanish National Institute of Statistics.

Altitude measures. Mean altitude of a region measured as meters over the sea level, and the standard deviation of the altitude. Source: *Statistical Yearbook,* Spanish National Institute of Statistics.

ANNEX

Table I
Simple Correlations among explanatory variables

	K/L	L	PC/L	H/L	POP	SUP	PD	ALT(m)	DALT(d)	U	CU	Trend
K/L	1.00	-	-	-	-	-	-	-	-	-	-	-
L	-0.301	1.00	-	-	-	-	-	-	-	-	-	-
	(-5.403)											
PC/L	0.593	-0.444	1.00	-	-	-	-	-	-	-	-	-
	(10.072)	(-7.065)										
H/L	0.316	-0.014	0.382	1.00	-	-	-	-	-	-	-	-
	(4.587)	(-0.220)	(5.987)									
POP	-0.247	0.987	-0.441	0.008	1.00	-	-	-	-	-	-	-
	(-4.877)	(96.711)	(-7.928)	(0.128)								
SUP	0.297	0.524	0.142	-0.187	0.549	1.00	-	-	-	-	-	-
	(4.912)	(10.514)	(2.036)	(-2.991)	(10.642)							
PD	-0.285	0.587	0.151	-0.206	0.539	0.524	1.00	-	-	-	-	-
	(-4.355)	(12.311)	(-2.255)	(-2.691)	(10.178)	(9.908)						
ALT(mean)	-0.314	0.129	0.342	0.160	0.135	0.327	0.278	1.00	-	-	-	-
	(-0.359)	(2.937)	(6.989)	(2.788)	(2.922)	(7.085)	(5.673)					
ALT(dev.)	-0.346	0.178	0.064	0.206	0.173	-0.035	0.289	0.626	1.00	-	-	-
	(-5.773)	(3.777)	(1.188)	(3.482)	(3.726)	(-0.527)	(6.555)	(8.551)				
U	0.328	0.217	0.100	0.404	0.327	0.194	-0.021	-0.027	0.020	1.00	-	-
	(4.885)	(3.117)	(1.420)	(5.884)	(4.821)	(3.017)	(-0.250)	(-0.409)	(0.268)			
CU	-0.182	0.011	-0.154	-0.072	0.326	0.000	0.000	0.000	0.000	0.070	1.00	-
	(-3.066)	(0.164)	(-2.629)	(-1.143)	(-0.016)					(-1.223)		
Trend	0.352	0.027	0.442	0.718	0.013	0.000	0.000	0.000	0.000	0.239	-0.210	1.00
	(6.114)	(0.409)	(7.472)	(15.219)	(0.198)					(3.495)	(-2.966)	

Table II

Regional Size. Relative to the Country

a) *KM^2*

Spain	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
100	17.3	9.4	2.1	1.0	1.5	1.1	18.6	15.7	6.3	4.6	8.2	5.8	1.6	2.2	2.1	1.4	1.0

Source: *Anuario Estadístico*, INE.

b) *Population*

Year	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	17.3	3.1	3.0	1.7	3.6	1.4	6.8	4.3	16.0	9.8	2.7	7.4	12.6	2.5	1.4	5.8	0.7
1985	17.8	3.1	2.9	1.7	3.7	1.4	6.7	4.3	15.7	9.8	2.8	7.3	12.6	2.6	1.3	5.6	0.7
1993	18.3	3.0	2.8	1.9	3.9	1.3	6.4	4.2	15.6	10.0	2.7	7.0	12.8	2.7	1.3	5.3	0.7

Source: *Contabilidad Regional de España*, INE.

Table III

Regional Population Dispersion. 17 Spanish Regions (CC.AA.)

Number of self-contained districts

SPAIN	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
60,808	3,078	1,543	6,818	288	1,101	958	6,149	1,698	3,947	1,148	622	29,179	829	958	952	1,285	255

Source: *Nomenclátor*, INE.

Altitude: Average

Meters over the sea level

SPAIN	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
730	564	854	700	164	588	649	1,014	894	689	524	446	521	909	594	613	488	886

Source: *Anuario Estadístico*, INE.

Altitude: Standard Deviation

Meters

SPAIN	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
199.7	205.1	221.6	225.4	84.1	251.1	220.1	150.7	150.0	236.8	167.7	83.4	155.7	178.5	172.2	142.1	138.9	203.7

Source: *Anuario Estadístico*, INE.

Altitude: Variation Coefficient

SPAIN	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
0.27	0.36	0.26	0.32	0.51	0.43	0.34	0.15	0.17	0.34	0.32	0.19	0.30	0.20	0.29	0.23	0.28	0.23

Source: *Anuario Estadístico*, INE.

Table IV

Sources of Labour Productivity Differencials in 1993

	Observed Labour Productivity (1)	Private Capital (2)	Labour (3)	Public Capital (4)	Human Capital (5)	Observed Fixed Effects (6)	Unemployment (7)	Predicted Labour Productivity (8)	Error (9)
AND	-0.07	-0.02	0.08	0.01	0.00	-0.08	-0.06	-0.08	0.00
ARA	0.05	0.04	-0.01	0.01	0.02	-0.03	0.03	0.06	-0.01
AST	-0.08	-0.01	-0.02	0.01	0.00	-0.02	0.00	-0.03	-0.05
BAL	0.22	0.00	-0.04	-0.05	-0.06	0.09	0.04	-0.02	0.23
CAN	-0.04	-0.02	-0.01	0.00	0.05	0.06	-0.05	0.03	-0.06
CANT	0.10	0.02	-0.07	0.02	0.01	0.07	0.01	0.06	0.04
C&L	-0.05	0.02	0.03	0.03	0.01	-0.12	-0.01	-0.03	-0.02
CM	-0.04	0.07	0.00	0.05	-0.04	-0.07	-0.01	-0.01	-0.03
CAT	0.11	-0.01	0.09	-0.04	-0.01	-0.04	0.05	0.04	0.07
RV	-0.06	-0.04	0.06	-0.02	-0.03	0.00	-0.03	-0.06	0.00
EXT	-0.24	0.09	-0.04	0.03	0.01	-0.03	-0.06	0.00	-0.23
GAL	-0.34	-0.06	0.04	-0.04	-0.08	-0.11	0.00	-0.25	-0.09
MAD	0.18	-0.05	0.07	-0.07	0.02	0.06	0.05	0.08	0.10
MUR	-0.15	-0.03	-0.03	-0.02	-0.03	0.04	-0.03	-0.12	-0.03
NAV	0.15	0.00	-0.06	0.03	0.08	0.03	0.06	0.14	0.01
BC	0.17	0.01	0.02	0.01	0.03	0.04	-0.02	0.09	0.08
RIO	0.08	-0.01	-0.10	0.04	0.03	0.12	0.03	0.10	-0.02

Table V
Regional Public Capital (Relative to the Country)

a) ***Total Public Capital***

Year	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	13.2	5.2	3.4	1.5	4.1	1.5	10.6	6.1	14.5	8.5	2.9	6.8	8.3	1.6	2.7	7.3	1.8
1985	13.8	4.7	3.6	1.3	3.4	1.2	7.9	4.6	11.7	7.2	2.2	5.6	6.6	1.4	1.9	6.5	1.2
1993	14.7	3.4	2.9	1.3	3.6	1.4	7.4	5.1	11.5	7.7	2.7	6.0	7.0	1.9	1.8	6.3	0.9

Source: BD. MORES.

b) ***Productive Public Capital***

Year	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	11.8	5.6	3.6	1.5	4.1	1.5	11.5	6.8	15.1	8.3	3.0	6.9	6.4	1.4	2.9	7.4	2.2
1985	12.7	5.1	3.9	1.5	4.0	1.5	11.1	6.5	14.8	8.9	2.8	6.7	6.5	1.6	2.5	8.0	1.5
1993	16.9	4.1	3.5	1.4	3.6	1.8	9.2	6.6	14.2	9.4	3.0	6.2	7.5	2.3	2.2	6.9	1.2

Source: BD. MORES.

Table VI

Regional Public Investment in Infrastructure (Relative to the Country)

a) ***Total Public Investment***

Year	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	14.0	3.8	4.8	1.9	5.6	2.0	9.1	4.5	12.2	6.5	1.9	9.9	12.2	1.6	1.7	6.7	2.0
1985	17.0	3.6	2.9	1.9	4.5	1.6	8.3	5.3	13.0	8.3	3.1	8.0	7.8	2.6	2.0	9.3	0.8
1993	17.3	2.8	3.5	1.4	3.4	1.8	7.4	5.0	13.4	10.5	3.8	7.3	10.2	2.6	1.8	7.4	0.6

Source: BD. MORES.

b) ***Productive Public Investment***

Year	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	13.6	3.4	5.4	1.3	6.1	2.3	9.1	4.5	12.8	5.7	1.6	11.1	10.2	1.1	2.1	7.2	2.5
1985	16.2	4.0	3.3	2.5	3.7	1.6	8.2	5.3	13.1	8.1	2.5	5.3	9.8	2.8	1.6	10.6	0.9
1993	18.8	2.0	3.6	0.8	1.9	2.7	6.9	5.4	13.6	13.1	3.1	5.6	11.9	3.0	1.6	5.5	0.3

Source: BD. MORES.

Table VII
Relative Public Capital (productive) INDEX
OLS Estimation (Equation [11])

	(1)	(2)	(3)
α	0.224 (11.935)	0.194 (9.990)	0.161 (11.482)
β	0.776 (41.357)	0.638 (30.652)	0.679 (36.715)
γ	-	0.104 (7.270)	0.093 (7.165)
δ_1	-	0.063 (10.222)	-
δ_2	-	-	0.067 (10.468)
Nº Obs	238	238	238
R^2	0.779	0.851	0.850
Se^2	0.349	0.286	0.287

t-Student in brackets; δ_1 is the parameter of average altitude and δ_2 the one of the standard deviation of altitude.

Table VIII

a) *Observed productive public capital. Growth rates.*

Year	Spain	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980-85	15.2	22.4	4.5	22.5	19.7	12.1	17.5	11.8	10.9	13.6	22.1	10.1	13.0	17.1	28.5	-1.2	22.2	-3.0
1985-93	46.7	75.4	25.8	37.7	40.1	35.9	61.8	27.9	48.6	42.5	51.8	51.8	38.8	60.5	80.8	35.2	32.1	3.2
1980-93	61.9	97.8	80.3	60.2	50.8	48.0	79.4	39.7	59.5	56.1	73.8	61.9	51.8	77.5	109.2	34.0	54.3	0.2

Source: BD. MORES.

b) Net Public investment on productive public capital (relative to the country)

Year	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1981	21.5	0.8	8.7	1.0	4.3	3.3	9.1	4.1	10.3	5.2	-1.3	12.0	9.7	1.4	-1.3	12.7	-1.5
1985	20.1	3.1	3.0	3.0	3.0	1.7	5.0	6.0	10.6	7.7	2.2	4.0	11.6	3.4	1.0	13.4	0.2
1993	22.0	-0.5	3.6	0.1	0.1	3.9	3.3	3.0	12.0	18.6	3.4	4.4	18.3	4.2	0.8	4.0	-0.9

Source: BD. MORES.

Table IX

a) ***Observed rates of return to productive public capital***

Year	Spain	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	0.45	0.48	0.27	0.41	0.67	0.36	0.46	0.26	0.24	0.58	0.52	0.24	0.41	0.97	0.71	0.27	0.47	0.17
1985	0.41	0.42	0.28	0.34	0.69	0.33	0.41	0.25	0.22	0.52	0.44	0.27	0.39	0.87	0.55	0.28	0.36	0.21
1993	0.32	0.24	0.27	0.24	0.57	0.29	0.26	0.21	0.18	0.45	0.33	0.18	0.30	0.64	0.31	0.27	0.32	0.22

Source: BD.MORES.

b) ***Virtual rates of return to productive public capital***

Year	Spain	AND	ARA	AST	BAL	CAN	CANT	C&L	CM	CAT	VR	EXT	GAL	MAD	MUR	NAV	BC	RIO
1980	0.45	0.48	0.27	0.41	0.67	0.33	0.46	0.26	0.24	0.58	0.52	0.24	0.41	0.97	0.71	0.27	0.47	0.17
1985	0.41	0.48	0.27	0.34	0.46	0.32	0.31	0.26	0.22	0.54	0.47	0.25	0.38	0.77	0.46	0.24	0.41	0.18
1993	0.32	0.38	0.23	0.21	0.24	0.23	0.17	0.23	0.21	0.50	0.36	0.17	0.28	0.53	0.21	0.18	0.31	0.12

Source: BD.MORES.

Table X
Virtual Productive Public Capital (Relative to the Country) in 1993

Regions	Neutral	Objective	Efficiency	Redistributive	Observed
Andalusia	11.8	14.0	10.0	10.5	16.9
Aragon	5.6	5.0	5.1	5.1	4.1
Asturias	3.6	3.7	4.2	5.3	3.5
Baleares	1.5	1.6	3.8	1.0	1.4
Canary Islands	4.1	3.9	4.6	4.7	3.6
Cantabria	1.5	1.6	2.9	2.1	1.8
Castile & León	11.5	10.3	8.1	10.6	9.2
Castile-La Mancha	6.8	6.3	5.5	7.3	6.6
Catalonia	15.1	14.3	12.6	9.7	14.2
Valencian Region	8.3	8.2	8.1	8.3	9.4
Extremadura	3.0	3.2	3.5	7.1	3.0
Galicia	6.9	7.9	6.5	10.9	6.2
Madrid	6.4	7.1	9.1	3.8	7.5
Murcia	1.4	2.1	3.5	4.5	2.3
Navarre	3.0	2.4	3.4	2.2	2.2
Basque Country	7.5	6.1	7.0	4.5	6.9
La Rioja	2.2	1.6	2.4	2.5	1.2

Table 1.A
Virtual Relative Labor Productivity 1980-1993

	Slope			
Years	**Neutral**	**Objective**	**Efficient**	**Redistributive**
1980	0.0338	0.0338	0.0338	0.0338
1981	0.0363	0.0362	0.0364	0.0360
1982	0.0356	0.0354	0.0360	0.0349
1983	0.0369	0.0366	0.0375	0.0357
1984	0.0333	0.0330	0.0341	0.0317
1985	0.0292	0.0287	0.0302	0.0269
1986	0.0308	0.0303	0.0320	0.0280
1987	0.0316	0.0309	0.0330	0.0285
1988	0.0285	0.0277	0.0301	0.0249
1989	0.0286	0.0276	0.0305	0.0241
1990	0.028	0.0268	0.0300	0.0225
1991	0.0270	0.0257	0.0292	0.0205
1992	0.0273	0.0259	0.0296	0.0203
1993	0.0267	0.0254	0.0291	0.0194

Figure 1.A
Spanish Gross Public Investment 1980-1993
1980 millions of pesetas.