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THE SPANISH TECHNICAL CHANGE: A REGIONAL AND A DYNAMIC ANALYSIS (1994-2007)

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THE SPANISH TECHNICAL CHANGE: A REGIONAL AND A DYNAMIC ANALYSIS (1994-2007)

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Abstract

Studying wage dispersion, many researchers have found that the skill premium (the ratio of skilled workers' wages to unskilled ones) has increased after 1979 in many developed countries, when there was a very sharp increase in the supply of skilled workers. The recent consensus is that technical change favours skilled workers, replacing tasks previously performed by the unskilled and exacerbating inequality. In the Spanish case, Nuñez and Alfaro (2009) have found evidences of a decline in the wage premium during the nineties. So, in this paper, we distinguish between skilled and unskilled workers differentiating the efficiency units of both types of workers. Moreover, we calculate the Spanish technology frontier and the technology differences between the Spanish Regions in 2006 and we analyze the evolution of the Spanish technology frontier over 1994-2007, testing the kind of technical change. In addition, a coherent Spanish wage micro-data base is achieved, using data from Eurostat: ECHP and EU-SILC.

Keywords: Technological frontiers; Technological differences; Technical change; Skills.
JEL classification: J24, O14, O33

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1. Introduction

A large and growing literature surveys and attempts to explain changes in wage dispersion in many developed countries over the past decades. Many researchers, like Ruiz Arranz (2001) or Acemoglu (2002), have studied the US case and they have found that returns to education fell during the 1970s, when there was a very sharp increase in the supply of skilled workers, and then began a steep rise during the 1980s. Furthermore, the skill premium (the ratio of skilled to unskilled workers wages) in the US has increased after 1979. In the Spanish case, Torres (2000) has studied skill premium to find out an increasing trend in the eighties whereas Nuñez and Alfaro (2009) show evidences of a decline during the nineties.

On the other hand, the last decades witness the rapid spread of computers to workplaces and lifestyles. So, the recent consensus is that skilled workers are more benefited from technical change, replacing tasks previously performed by unskilled workers, and exacerbating inequality in developed countries (Acemoglu 2002). Nevertheless, this trend is not the same everywhere. For example, Naticchioni et al. (2008) study the empirical relationship between wage inequality and technological change in Italy during the period 1993-2004, finding evidence that wage inequality in Italy can hardly be interpreted in terms of a skill-biased technical change. Moreover, the Italian case might be seen as an outlier with regard to the skill-biased technological change phenomenon, as the relative supply of skilled labor increases more than the demand for high-skilled occupations. Thus, these authors consider this occupational mismatch as a partial explanation for the decreasing wage premium.

Through a production function analysis, the relation between skilled and unskilled labor productivities and technical change is investigated. Differentiating the efficiency units of both types of workers we calculate the Spanish technology frontier and the technology differences between the Spanish Regions in 2006. Moreover, we analyze the evolution of the Spanish technology frontier between 1994 and 2007, testing the kind of technical change occurred in that period.

The paper is organized as follows. In Section 2, we review some relevant literature on educational wage premium, technological change and production functions, and we define the basic model. The data bases are described in Section 3, as well as some descriptive statistics related to the main variables to be used. In Section 4, we present the obtained results and, finally, the conclusions are drawn in Section 5. In an Appendix, the values of used variables in the study can be extensively found.

2. Methodology

Methodology is going to be presented through three subsections. First of all, relevant literature is reviewed. Next, concepts related to production functions are discussed and then the model to be used is defined in the last subsection.

2.1.- Literature Review

The explanations about changes in wage structure have been studied since the past decades and there are several applied methodologies to explain them. Katz and Murphy (1992) study the U.S. case over the period 1963-1987. They conclude that fast growth in the relative demand for skilled workers is a key component of any consistent explanation for rising inequality and changes in the U.S. wage structure over the analysed period. Their results indicate that observed fluctuations in the growth rate of the relative supply of college graduates combined with smooth-trend demand growth in favor of more-educated workers can largely explain fluctuations in the skill premium over the studied period. Steady demand growth in favor of skilled workers over the last decades appears consistent with both movements in educational differentials and within-group inequality.

Although there is a consensus on the facts regarding wage inequality, there is disagreement on the explanations for increased wage inequality. Confronted hypothesis are increased globalization pressures and changes in institutional factors such us the decline of unions and the real value of the minimum wage. However, many studies hold skill-biased technical change as responsible for the increased wage inequality. Most of the authors view the increase in inequality over the past decades as a direct consequence of technical change associated with the spread of computers-based technologies (Bound and Johnson, 1992). The so-called new economy would have tended to make skilled workers more efficient and to replace tasks previously performed by unskilled ones despite the rising relative price of the more educated workers (Acemoglu, 2002). The same author argues that, in absence of substantial skill bias in technology, the large increase in the supply of skilled workers during the last 60 years would have depressed the skill premium.

Katz and Murphy (1992) present a simple supply-demand model that accounts for much of the variation in the skill premium over time in the U.S. case. In this model, they specify the log of skill premium as a function of both a linear trend and the log of the ratio of unskilled to skilled labor input. They interpret the time trend as the relative demand shifter for skilled labor associated with advanced technology, the spread of computers, etc.

Many studies followed Katz and Murphy's paper trying to explain the time trend of their equation. They have found that explaining the increase in the skill premium on the basis of observable variables is difficult and they have concluded implicitly that latent skill-biased technical change must be the main factor responsible. Bound and Johnson (1992) reached the same conclusion after studying different explanations. Krusell et al. (2000) examine that point of view systematically. They develop a framework that provides an explicit economic mechanism for understanding skill-biased in terms of observable variables, and they use it to evaluate the share of variation in the skill premium that can be explained from the changes in observed factor quantities. Moreover, they found that only changes in observable inputs can account for most of the variations in the skill premium over the last 30 years in the U.S. case, with capital-skill being complementary.

Ruiz Arranz (2001) develops a more general framework which allows, and disentangles the effects of both capital-skill complementarity and skill-biased technological change, as driving forces behind increased wage inequality. This proposal allows for different technical change biases, it does not assume any complementarity-substitutability pattern between the inputs, and all types of interactions are allowed. The main findings of this paper can be resumed in two: in first place, both skill biased technical change and capital-skill complementarity have taken place over the period 1965-1999 in the U.S. case and secondly, ignoring either of them will limit the understanding of the historical variation in the skill premium.

Torres (2000) researches the evolution of employment and wage for the Spanish case, distinguishing between skilled and unskilled workers. He develops a structural analysis, as well as a non-structural one. He concludes that capital-skill complementarity is a key factor in the increase of skill premium for the Spanish case in the eighties.

Despite the main objective of Caselli and Coleman II (2006) is uncovering the evidence of skill biased in cross-country technology differences, they also sketch a possible theoretical explanation for their findings. They develop a model that separately identifies efficiency units embodied in both unskilled and skilled labor in a country's aggregate production function. Applying that framework to cross-country data, they show that countries where unskilled labor is relatively abundant are those with the most efficient unskilled workers. What's more, countries where skilled labor is abundant are the most efficient users of skilled workers. The authors interpret their findings as evidence of appropriate-technology adoption: in each country firms choose from a menu of technologies; different technologies imply different combinations of values for the efficiency units embodied in the production factors; each country chooses the technology that makes the most of the most abundant factors.

Their paper investigates the implications of relaxing the assumption of perfect substitution of different types of labor, and it shows cross-country evidences on factor prices – particularly skill premium. In order to achieve it, they generalize the production function. The next section is a review of the several production functions used in different studies in the last years, and finally, the model used in the paper is presented.

2.2. – Model approaches related to production functions

Krusell et al. (2000) used a neoclassical aggregate production function, in which the key feature is the capital-skill complementarity. This means the elasticity of substitution between capital equipment and unskilled labor is higher than that between capital equipment and skilled labor. A key implication of capital-skill complementarity is that growth in the equipment stock increases the marginal product of skilled labor, but decreases the marginal product of unskilled labor.

In this paper, the authors evaluate how much the effect of capital-skill complementarity on the skill premium in the post-war period is. In doing this, they develop an aggregate production function depending on four factors: capital equipment (K_e), capital structures[1] (K_s), skilled labor (L_s) and unskilled labor (L_u); this proposal allows for different substitution elasticities among the factors.

They assume that the production function is one of Cobb-Douglas type, defined over the capital structures and over a Constant Elasticity Substitution (CES) function of the three remaining inputs. They choose the CES specification because its simplicity, because it has relatively few parameters, and it restricts substitution elasticities to be constant. There are three ways of nesting capital equipment, unskilled labor and skill labor within a CES function, two of which allow for capital-skill complementarity:

$$Y_1=F_1(L_s, F_2(K_e,L_u)) \quad \text{and} \quad Y_2=F_1(L_u, F_2(K_e,L_s)),$$

[1] They distinguish between two types of capital and they justify this, explaining that they have been growing at different rates since the late 1970s.

where F_1 and F_2 are CES aggregators. The CES functional form imposes symmetry restrictions on substitution elasticities. In the case of Y_1, the elasticity of substitution between skilled labor and capital equipment is restricted to be the same as skill and unskilled labor substitution elasticity. However, this restriction disagrees with other factor elasticity estimates, because these last ones suggest that the substitution elasticity between skilled and unskilled labor is higher than the substitution elasticity between skilled labor and capital (Hamermesh, 1993).

In the case of Y_2, the CES function restricts the elasticity of substitution between unskilled and skilled labor to be the same than unskilled-labor and equipment capital one. This restriction does not disagree with existing elasticities estimates. Moreover, the first specification is not as consistent with the data as the second specification. Therefore, they use the second function in their analysis:

$$Y_t = K_{st}^{\alpha}\left\{\mu L_{ut}^{\sigma} + (1-\mu)\left[\lambda K_{et}^{\rho} + (1-\lambda)L_{st}^{\rho}\right]^{\sigma/\rho}\right\}^{(1-\alpha)/\sigma} \quad (1)$$

In this expression, μ and λ are the parameters that governs the income share, and σ and ρ (σ,ρ <1) rule the elasticity of substitution between unskilled labor, capital equipment, and skilled labor. The substitution elasticity between capital equipment (or skilled labor) and unskilled labor is $1/(1-\sigma)$, and the substitution elasticity between capital equipment and skilled labor is $1/(1-\rho)$. Capital-skill complementarity requires that $\sigma>\rho$. If either σ or ρ equals zero, the corresponding nesting is Cobb-Douglas.

To understand the specific role of the capital-skill complementarity in the prediction of their model, the authors estimate the skill premium without capital-skill complementarity. To do this, they calculate the substitution elasticity between skilled and unskilled labor, but restrict the substitution elasticity between capital equipment and the two types of labor to be the same. By shutting off the capital-skill complementary effect, this exercise isolates the relative quantity effect on the skill premium. The model without capital-skill complementarity predicts that the large increase in skilled labor would have reduced the skill premium by 40 percent over this period. However, their benchmark model predicts an increase of 20 percent. By doing this, the authors show that skill-capital complementarity is a key component for understanding the skill premium increase in the U.S. case.

Caselli and Coleman II (2006) estimate the world technology function, relaxing the assumption of perfect substitution between workers. The underlying basic idea of their model is that, in each country, firms choose from a menu of different production functions that differ in the way they combine skilled and unskilled workers. Each of these methods determines a different production function. To capture the idea that different production functions use different inputs more or less efficiently, they assume that production functions differ in the parameters A_u and A_s, which convert raw quantities of the two types of labor into efficiency units. Hence, they represent the menu of possible choices of production function by a set of possible (A_u, A_s) pairs. Thus, no country will use a production function characterized by a certain pair (A_u, A_s) when another production function exists such that both A_u and A_s are higher, so only no-dominated (A_u, A_s) pairs are relevant. Their called the set of no-dominated (A_u, A_s) pairs a "technology frontier". The full definition and meaning of A_u and A_s will be offered later.

So, these authors develop a framework that identifies the efficiency units of skilled and unskilled labor separately and they use their model to cross-country data to find that there is a skill bias in cross-country technology differences. Higher income-countries use skilled workers more efficiently that lower-income countries, while they use unskilled workers relatively and, possibly, absolutely less efficiently. To explain it they argue that rich countries, which are skilled-labor abundant, choose technologies more appropriated to skilled workers, while poor countries, which are unskilled-labor abundant, choose technologies best fitted to unskilled workers.

Thus, they hold that cross-country technology differences will be skilled-labor (unskilled-labor) augmenting if A_s (A_u) tends to be higher in higher-GDP countries, i.e., richer countries use skilled labor (unskilled labor) more efficiently than poor countries. Furthermore, cross-country technology differences are skill-neutral if all countries have the same ratio A_s/A_u, and skilled-biased (unskilled-biased) if A_s/A_u tends to be higher (lower) in higher-GDP countries. To distinguish between the weaker and the stronger version of their result, they refer to the trend of A_s/A_u to be higher in rich countries as *relative skill bias*, and the tendency of A_s to be higher and A_u to be lower in rich countries as *absolute skill bias*.

In a cross-time context, technical change is skilled-biased if it increases the marginal productivity of skilled labor relative to unskilled labor. In a cross-country context, cross-country technology differences are skilled-biased if the marginal productivity of skilled labor relative to unskilled labor is higher in rich countries.

2.3. Caselli and Coleman model description

They consider an economy with a large number of competitive firms. Each firm generates output modelled through the following production form:

$$y = k^{\alpha}\left[(A_u L_u)^{\sigma} + (A_s L_s)^{\sigma}\right]^{\frac{1-\alpha}{\sigma}} \quad (3)$$

The firms hire two types of labor (skilled and unskilled) and capital, taking the prices as given: w_s, w_u and *r.* Firms choose optimal factors inputs as well as the production function. The production functions differ in the parameters A_s and A_u and the set of possible technology choices is given by:

$$(A_s)^{\omega} + \gamma (A_u)^{\omega} \leq B \quad (4)$$

where *ω, γ* and *B* are strictly positive and exogenous parameters. So, changing production function involves a trade-off between efficiency of both unskilled and skilled labor. This trade-off is governed by the parameters *ω* and *γ*, and *B* determines the technology frontier's height. The functional form of equation (4) is chosen by technical convenience, but it is rather flexible and it captures the trade-off idea related to technology choices.

Therefore, in each country, the representative firm will maximize profits (y- $w_s L_s$ - $w_u L_u$ – rk) with respect to L_s, L_u, k, A_s y A_u restrict to (3) and (4), the latter equation set out with equality. *r* is the firms´ cost of capital. Finally, they assume that the economy's endowment of L_s, L_u and *k* are all inelastically supplied[2]. *Equilibrium* describes a situation where all the firms maximize

[2] The important results would not change if capital is assumed to flow freely in and out of the country at some given world cost of capital, *r.*

profits and all inputs are fully employed. Thus, these authors prove in their paper that equilibrium exists and it is unique. Furthermore, they prove:

1) If $\omega>\sigma/(1-\sigma)$, equilibrium is symmetric: all the firms choose the same technology (A_u, A_s) and the same factor ratios L_s/k and L_u/k.

2) If $\omega<\sigma/(1-\sigma)$, equilibrium is asymmetric: some firms set $A_u = 0$ and employ only skilled workers and some others set $A_s = 0$ and employ only unskilled workers.

The condition $\omega>\sigma/(1-\sigma)$ is needed to rule out corner decisions, where the firms choose different technologies. Its meaning is rather intuitive. When σ is low, the workers are poor substitutes and the firms will prefer to operate with both inputs L_s and L_u. If both inputs are employed, the better case is where the efficiency units A_u and A_s are strictly positive. While σ becomes large, workers became better substitutes, and it makes more sense to use only one input and maximize the efficiency of that input. The condition stands that this will happen when σ becomes sufficiently large relative to ω. In addition, ω regulates the concavity of the technology frontier (a higher ω pushes frontier farther away from the origin, making interior technology choices more attractive to the corners). The condition for a symmetric equilibrium is always satisfied if $\sigma<0$.

Assuming that the condition for the existence of a symmetric equilibrium is satisfied, this equilibrium's properties are examined. Thus, each firm's first-order conditions include:

$$\left(\frac{L_s}{L_u}\right)^{1-\sigma} = \left(\frac{A_s}{A_u}\right)^{\sigma} / \frac{w_s}{w_u} \quad (5)$$

$$\left(\frac{A_s}{A_u}\right)^{\omega-\sigma} = \gamma\left(\frac{L_s}{L_u}\right)^{\sigma} \quad (6)$$

Equation (5) combines first-order conditions for L_s and L_u and it shows that the optimal choice of L_s/L_u is decreasing in w_s/w_u. For σ>0 (good substitutability between skilled and unskilled labor) it also shows that the greater the relative efficiency of L_s, the greater desired relative employment of L_s. For σ<0 (poor substitutability between skilled and unskilled labor), L_s/L_u decreases in A_s/A_u, as the firm tries to increase the productivity of inefficient input (and hence effectively scarce).

Equation (6) is the first-order condition with respect to A_u. It describes how technology choice depends on the quantities of inputs employed. For σ>0, the symmetric-equilibrium condition, ω>σ/(1-σ), implies ω-σ>0. Hence, firms employing a lot of skilled labor tend to choose technologies to augment skilled-labor relative to unskilled labor. Conversely, if σ<0, firms tend to drive technology choice toward the scarce input.[3]

Now the general equilibrium of the economy is examined. Since equilibrium is symmetric, equation (6) hold for L_s/L_u equal to the economy's endowment. Hence, with σ>0 (when inputs are relatively good substitutes), countries with abundant unskilled labor will choose relatively unskilled-labor-augmenting technologies while, with σ<0 (when inputs are poor substitutes), countries with abundant unskilled labor will try to improve the productivity of skilled labor. In other words, when inputs are good substitutes, countries make the most of the abundant input, while when they are poor substitutes, it is optimal to increase the effective supply of the scarce input.

[3] The first-order condition with respect to capital plays no role in this analysis.

Since Caselli and Coleman's framework implicitly characterize the "World Technology Frontier", in this paper we use this model to build the "Spanish Technology Frontier" in 2006 as well as to study the technology differences among its regions. Moreover, the evolution of Spanish technical progress between 1994 and 2007 is studied.

We begin using equations (3) and (5) to solve the unknown parameters A_s and A_u. Hence, each Spanish region's technology pair (A_u, A_s) is back out, so that measured inputs to production are exactly consistent with measured output and skill premia. Also, there is a Spanish technology pair (A_u, A_s) per year. Then, from (3) and (5):

$$A_u = \frac{y^{1/(1-\alpha)} k^{-\alpha/(1-\alpha)}}{L_u} \left(\frac{w_u L_u}{w_u L_u + w_s L_s} \right)^{1/\sigma} \quad (7)$$

$$A_s = \frac{y^{1/(1-\alpha)} k^{-\alpha/(1-\alpha)}}{L_s} \left(\frac{w_s L_s}{w_u L_u + w_s L_s} \right)^{1/\sigma} \quad (8)$$

So, we need data related to y, k, L_s, L_u, and w_s/w_u, as well as the values of α and σ. The parameter α measures the capital share in GDP, and to make easier comparisons with other works, we set α=1/3 as the standard convention. The parameter σ is related to the elasticity of substitution between skilled and unskilled labor, 1/(1-σ), so in the initial analysis we test with a variety of values within the range 1-2.[4] Moreover, our preferred value for the Spanish case is when substitution elasticity equals 1.7. [5] In the next section we present data and obtained

[4] Autor et al. (1998) conclude that the substitution elasticity is very unlikely to fall outside the range 1-2.
[5] See Torres (2000).

results. Although all results presented in this research are based on a CES function with two types of workers, they are not consequence of the functional form used[6].

3. Data description

In this section, we present the data-bases used to obtain the analysed variables as well as a brief description of some of them.

3.1. Data Bases

Data for GDP come from the website of the Spanish National Statistics Institute (INE) and the labor aggregates are obtained from Penn World Table Version 6.3's data base[7]. Capital stock is obtained through the estimations provided by BBVA Foundation and IVIE Institute. They calculate three types of capital: gross, net and productive, but in this paper we use productive capital stock because it is the best to valuate the contribution of capital to production[8].

One of the contributions of this investigation is the construction of the labor aggregates L_u and L_s, as well as the skill premia w_s/w_u at a microeconomic level for the Spanish case. So, labour force proportions of unskilled and skilled workers and skill premium are obtained, using 1994-2001 data from Eurostat´s ECHP, and 2004-2007 data come from Eurostat´s EU-SILC database. Wages and proportions of different workers are estimated from samples composed of wage-earnings employees aged 16-64 who declare their studies, net salaries and the numbers of hours they work per week. So, we compute the net salary per hour.

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[6] See Caselli and Coleman II (2006) for more information at this point.
[7] See Heston, Summers and Aten (2009) for data description.
[8] See Mas *et al.* (2008) for more details.

In the 2002-2003 period, we tried to use the Continue Survey of Household Budgets (ECPF, its acronym in Spanish), but the resultant data were not homogenous with the data resulting from the other Surveys (ECPH and EU-SILC). Thus, we decided to interpolate the results for these 2 years in such a way the tendency remains unchanged.

We first consider two types of threshold to classify the workers as “unskilled” or “skilled”. Thus, first classification considers high school graduates as skilled workers and those who are not unskilled. In the second classification, workers with high school degrees are unskilled workers and those with studies higher than complete high school level are considered skilled workers. Our reference case will be the first one.

3.2. Descriptive Statistics

As an introduction, we present some trends related to the most relevant variables for both Spain and the Spanish Regions cases in Figures1-4. The values of these variables are shown in tables A.1 and A.2, placed in the Appendix.

[Insert Figure 1]

The evolution of the product and the capital per worker in Spain between 1994 and 2007 is shown in Figure 1. Clearly, both tendencies are positive. Moreover, from 1994 to 2001 both variables grew at the same level, but capital per worker grew faster than product per worker the last 5 years of the analysis.

[Insert Figure 2]

Figure 2 plots the time paths of the (log) skill premium and the (log) relative demand of skilled and unskilled workers. Same as many developed countries, the Spanish's trend of relative demand of skilled and unskilled worker is positive. However, the skill premium has been reduced in the analysed period. This pattern can be considered divergent with other developed countries where this premium has increased considerably.

[Insert Figure 3]

Product and capital per worker for the different Spanish regions in 2006 are shown in Figure 3. In this graph, we can notice how the product per worker is very similar among the different regions (its range of variation is 20,000 Euros); but this is not the case of capital per worker, since its range of variation is 80,000 Euros. Also, we can see that richer regions (the ones with higher product) are not those with higher capital per worker. Thus, regions like Extremadura or Castilla-La Mancha[9] are zones with high levels of capital per worker and low levels of product. Regions like Madrid or Cataluña are among the ones with higher product and lower capital. Thus, we could say that the richest areas are the most productive ones.

[Insert Figure 4]

Figure 4 shows the skill premium for the different Spanish regions in 2006 (Skilled workers are those who have completed high school studies). There we can see that regions with the highest product per worker are those with the highest and the lowest skill premia, at the same

[9] Table A.2 (Appendix) show the numbers assigned to the different Spanish regions, from 1 to 17.

time. Zones like Madrid, Islas Baleares or Cantabria have the highest skill premium and Navarra, La Rioja or País Vasco show the lowest.

[Insert Figure 5]

Figure 5 shows the relationship between product per worker and the relative demand for skilled to unskilled workers, as well as the relation of the former with skill premium in the different Spanish regions in 2006. It is clear that rich regions (zones with high levels of product) demand more skilled workers than unskilled ones. However, the relation between product and the skill premium is ambiguous.

Thus, after a brief description of some interest's variables, we estimate, in next section, the model for the study of the technological progress in the Spanish case.

4. Estimations and Results

First of all, in this section we present the regional analysis, as well as the estimation of the Spanish technology frontier for 2006. At the end, we show the evolution of the efficiency units in the period between 1994 and 2007.

4.1. Regional Estimation (2006)

Once A_s and A_u are calculated for the different regions, for different proportions of labor force and for different values of substitution elasticity between skilled and unskilled labor, we regress $ln(A_s)$, $ln(A_u)$, as well as $ln(A_s/A_u)$, all with respect to $ln(y)$. Regression coefficients are presented in Table 1 for different values of elasticity substitution.

The main idea is to study the technology differences in Spanish regions. Thus, if rich zones (zones with high levels of y) have bigger A_s, technical differences will be skilled biased, since the productivity of skilled worker is higher, i.e., when richer countries use skilled labor more efficiently than poor countries. The tendency of A_s/A_u to be higher in rich countries is called *relative skill bias*, and the tendency of A_s to be higher and A_u to be lower in rich countries is named *absolute skill bias*.

[Insert Table1]

We can see in Table 1 that technology differences in the Spanish regions are skilled-labor augmenting, both in relatively and absolutely senses. It is relatively, because richer regions use skilled worker more efficiently than poor countries (regression coefficients are positives for skilled workers) and it is absolutely, because they use unskilled worker less efficiently than poor zones (regression coefficients are negative for unskilled workers). Our reference case (an skilled worker is one who has completed high school studies and the elasticity of substitution between skilled and unskilled labor is 1.7) is statistically significant. From now on, we use our reference case in subsequent analysis.

[Insert Figure 6]

[Insert Figure 7]

Thus, Figures 6 and 7 present the negative relation between A_u and *y,* and the positive relation between A_s and *y*, respectively. Regions with higher GDP show more efficiency in the use of skilled worker and poor zones are more efficient using unskilled worker.

[Insert Figure 8]

[Insert Figure 9]

Figures 8 and 9 show the same information as Figures 6 and 7, but in a different way. Actually, the difference relies on the fact that the last ones are labelled showing what Spanish regions they are. As expected, zones like Madrid, País Vasco or Cataluña are the most efficient in the use of skilled workers. Regions like Murcia, Andalucía and Canarias use unskilled labor more efficiently. The last ones are touristic zones.

4.1.1. The Spanish Technology Frontier

Caselli and Coleman II's model can be used to extract interesting quantitative implications; for example, the importance of the use of the appropriated technology according to each region's endowments (capital, unskilled workers and skilled workers). Thus, we can analyse how severe is the trade off the regions must face in their technologies choice. In doing so, we calculate the production function for each region.

So, relaxing the assumption that all countries must face the same trade-off parameter (γ) is the first step, and thus to allow each region's realization of γ to be a random variable uncorrelated with its endowments. Using this last assumption, we can rewrite (6) in logs as:

$$\log\left(\frac{A_s^i}{A_u^i}\right) = \frac{\sigma}{\omega-\sigma}\log\left(\frac{L_s^i}{L_u^i}\right) + \frac{1}{\omega-\sigma}\log\gamma^i \quad (9)$$

Then, an estimate of σ/(ω-σ) can be obtained by regressing:

$$\ln\left(\frac{A_s^i}{A_u^i}\right) = b^i \ln\left(\frac{L_s^i}{L_u^i}\right) + u^i$$

We can back out ω from this estimation and the calibrated value of σ. Furthermore, each region's trade-off coefficient γ^i can be recovered from the regression residual. Thus, using the obtained values of γ^i and ω, we can trace back each region's B^i from equation (4), and hence, its technology frontier. To do so, we will use our reference case.

The values we estimate[10] are ω=0.48 and γ=1.0824. Figure 10 depicts Spanish's Regions technology choices (A_u, A_s) for 2006 and Figure 11 shows some Spanish's region frontiers drawn from highest to lowest: Islas Baleares, Madrid, Galicia and Extremadura.

[Insert Figure 10]

Associated with each Spanish region frontier, we can identify the Spanish Technology Frontier as the outer envelope of the region-specific frontiers. In other words, for each A_u, we maximize over all of the Spanish' region frontiers to find the maximum possible value of A_s. This envelope matches entirely with frontier of Islas Baleares. It is not surprising that Islas Baleares has had the highest technology frontier, given that Islas Baleares' skilled labor is one of the

[10] These values are back out from a regression coefficient of 1.1569. The R^2 associated to the regression is 0.75.

most productive of the Spanish´s regions as well as unskilled labor case. Moreover, its unskilled labor is more productive than Madrid or País Vasco's unskilled labor. Furthermore, Islas Baleares has a low level of capital, but its GDP is higher than the average. Checking out each region's position relative to the Spanish' technology frontier reveals that poor regions are typically farther away from the Spanish' frontier than the rich ones.

[Insert Figure 11]

4.2. National Dynamic Estimation (1994-2007)

In this section, we applied the same framework to evaluate the evolution of the Spanish's technology choices (A_u, A_s) between 1994 and 2007. Figures 12 and 13 present the evolution of the efficiency of skilled and unskilled labor between 1994 and 2007. This graphs show a positive trend in the efficiency of both types of worker, however the skilled labor's efficiency grew more than unskilled labor one.

The same information is shown in Figure 14 and 15, but labelled by year. Focussing on this label, we can see in detail the continuous growth of the Spanish's GDP associated with the efficiency of skilled workers and, in a lower degree, with the efficiency of the unskilled workers.

[Insert Figure 12]

[Insert Figure 13]

Although the databases we use do not include many years, one of the contributions of this paper is the construction of a homogeneous salary database from them (micro-data bases), and even though we have few years for a robust regression, we consider interesting to do it keeping in mind the limited scope of the results.

[Insert Figure 14]

[Insert Figure 15]

Table 2 shows the coefficients of the regressions of log(A_u) on log(y) and log(A_s) on log(y). In our reference case, the coefficients of efficiency of both workers are statistically significant, but the differences are not. So, we can say that in Spain the technological change in the last years has been relative skilled-biased. In other words, the technology employed in Spain, has increased more the efficiency of the skilled worker than the efficiency of the unskilled labor.

[Insert Table2]

In Figure 16, we can see Spanish's technology choices in the analysed period. It is important to notice that the break in the database coincides with the entrance of Spain in the European Union, so we can see how the efficiency of both types of worker have been favored.

[Insert Figure 16]

5. Conclusions

During the last decades, in many developed countries the relative wages of skilled labor have grown significantly despite the fact the relative quantity of the skilled to unskilled workers have increased considerably. As a consequence of those events, a great amount of literature has appeared trying to explain them. Although there are many hypothesis trying to explain these trends like increased globalization pressures or institutional factors such us the decline of unions, the consensus nowadays is that the skill-biased technical change is the most plausible responsible.

However, countries like Spain or Italy show a decrease in the skill premium trend. So, in this paper we study the evolution of the technology choices in Spain between 1994 and 2007. Moreover, we present the Spanish Technology Frontier in 2006 through a regional analysis of the Spanish case. Both analyses together with the study of the evolution of the efficiency of unskilled and skilled labor allow us to extract some interesting conclusions.

In the regional analysis, we observe that technological differences are absolute skill-biased. In other words, the rich regions use the skilled labor more efficiently than poor zones, and they use the unskilled labor more inefficiently. Drawing the technological choices of the Spanish's regions, we conclude that the Spanish Technology Frontier in 2006 is set by Islas Baleares's frontier. This zone is one the richest, and the efficiency of its skilled labor is high as well as the efficiency of their unskilled workers.

In the national dynamic estimation, we concluded that the technical change in Spain have been relative skill-biased; in other words, the rise in the product increase the efficiency of both types of workers, especially the efficiency of skill labor. Although this conclusion has been made from a regression analysis using a few years, the main interest of this database relies on the creation of a homogenous salary data base for Spain (using micro data).

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Figure 1: Evolution of the product and capital per worker in Spain (1994-2007)

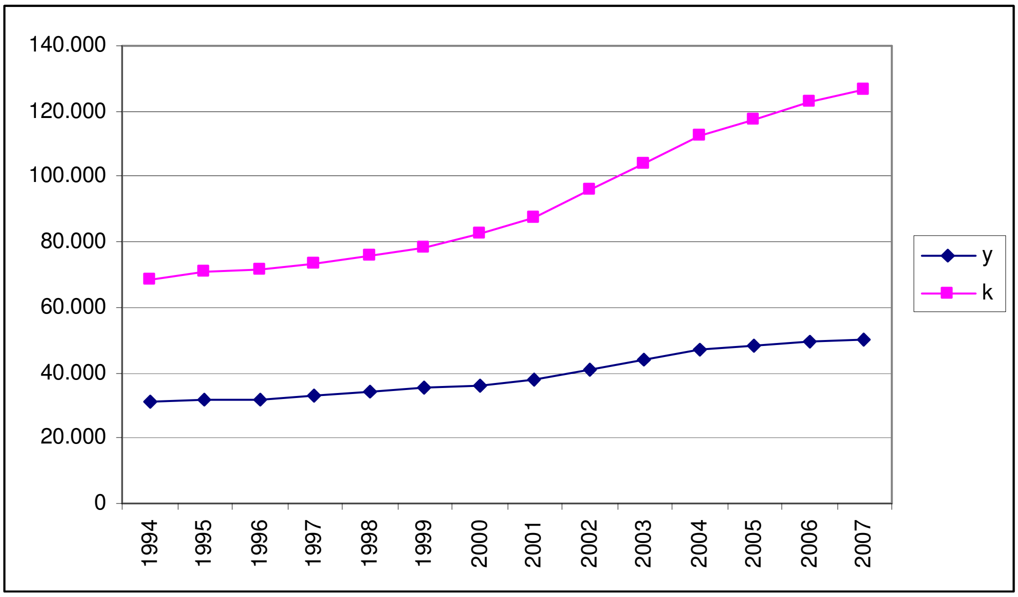
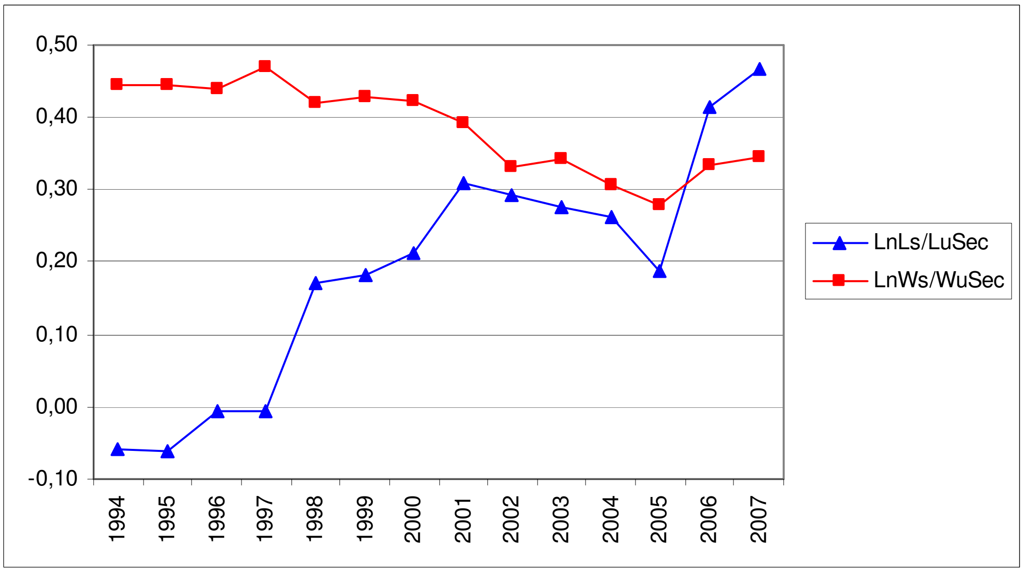


Figure 2: Log skill premium and Log relative demand of skilled and unskilled workers, Spain (1994-2007)



Note: Skilled workers are those who have completed high school studies.

Figure 3: Product and capital per worker, Spanish Regions 2006

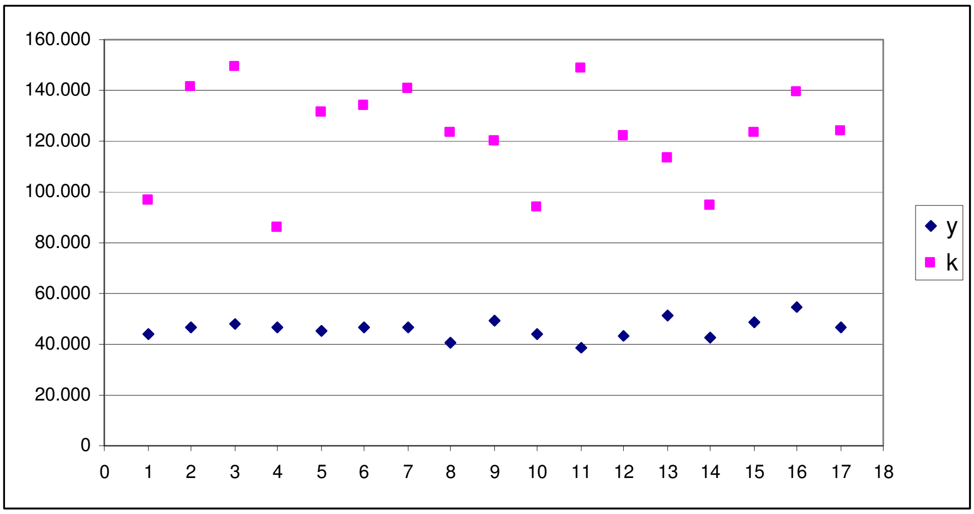
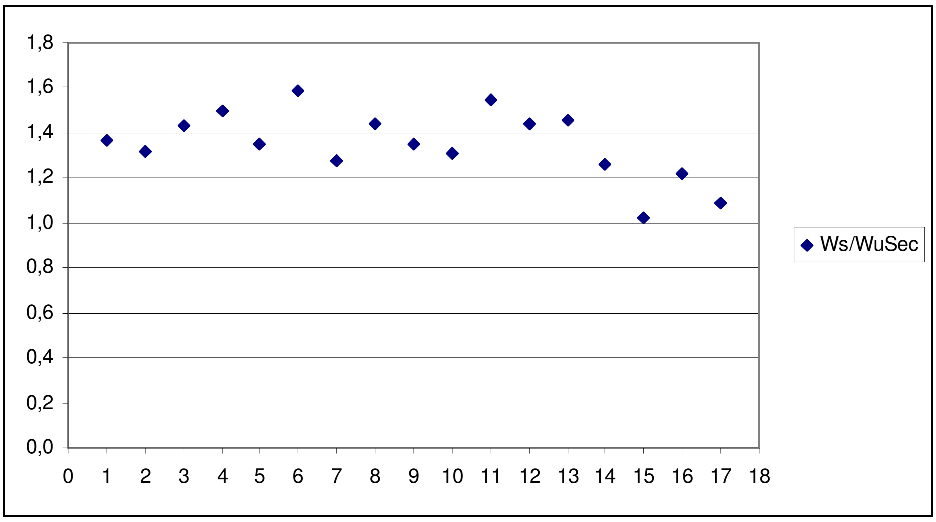


Figure 4: Skill premium for Spanish Regions, 2006



Note: Skilled workers are those who have completed high school studies.

Figure 5: Product per worker and the relative demand of skilled to unskilled worker and the skill premium, 2006

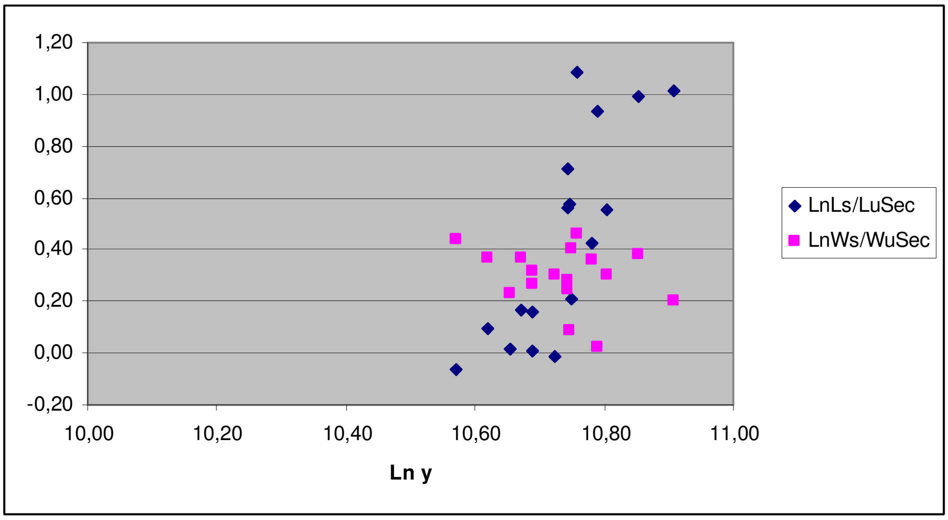


Figure 6: Efficiency of unskilled labor, 2006

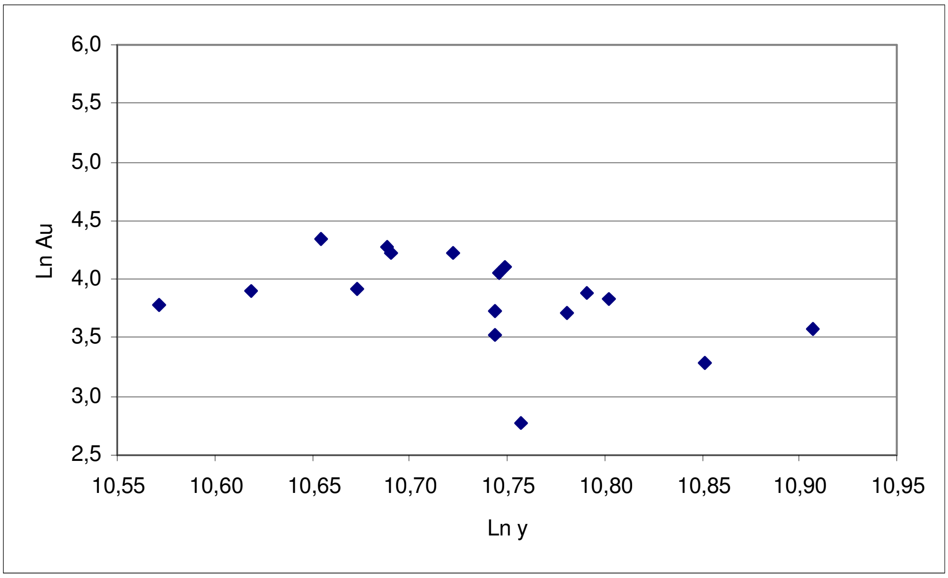


Figure 7: Efficiency of skilled labor, 2006

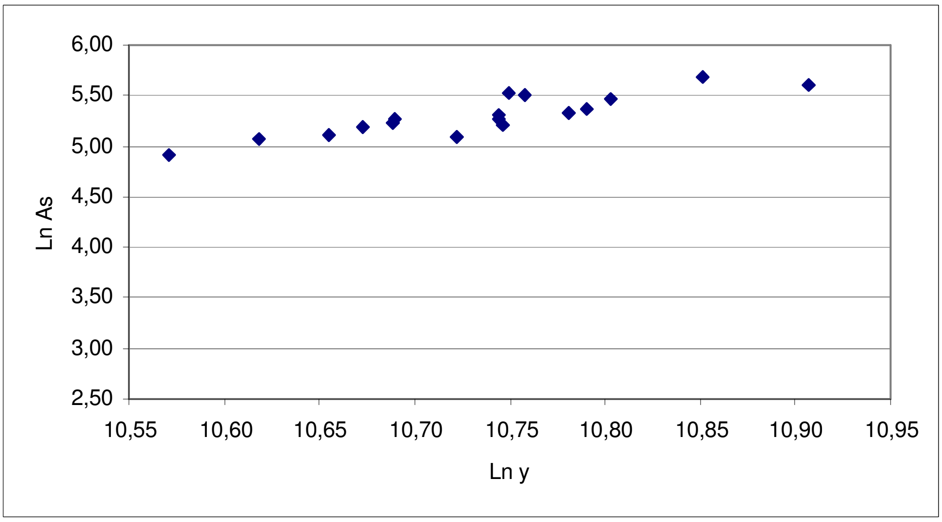


Figure 8: Efficiency of unskilled labor, labelled for Spanish regions

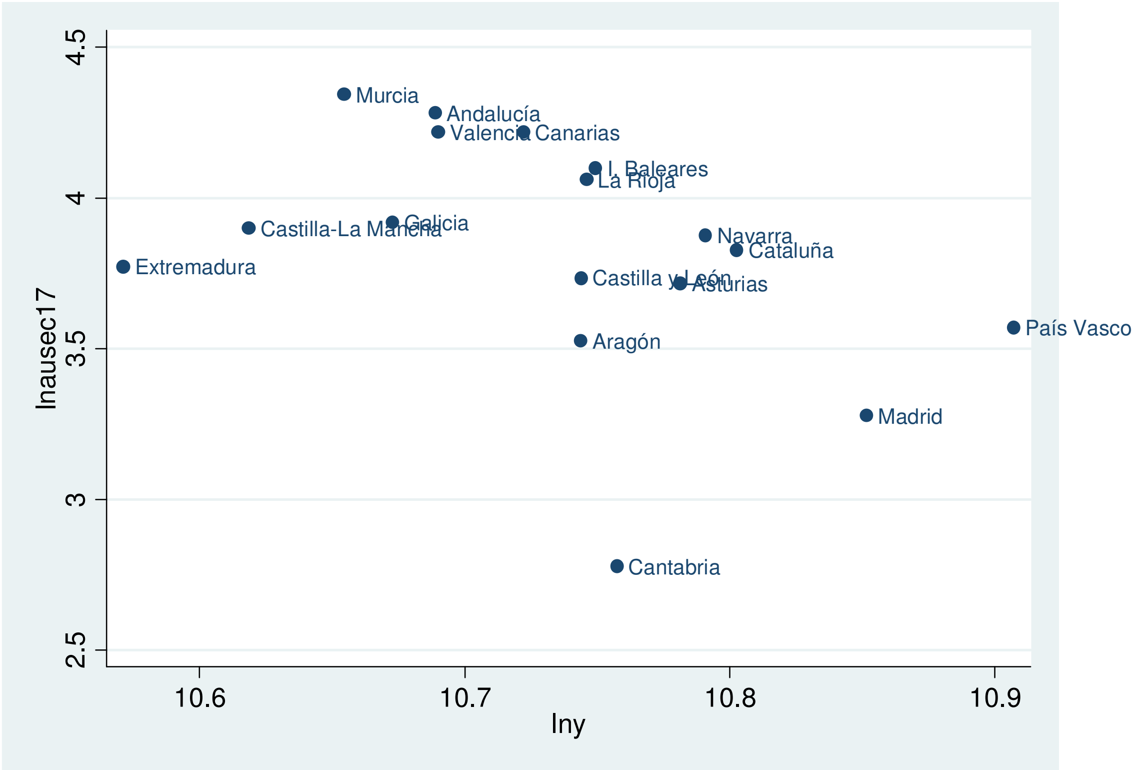


Figure 9: Efficiency of skilled labor, labelled for Spanish regions

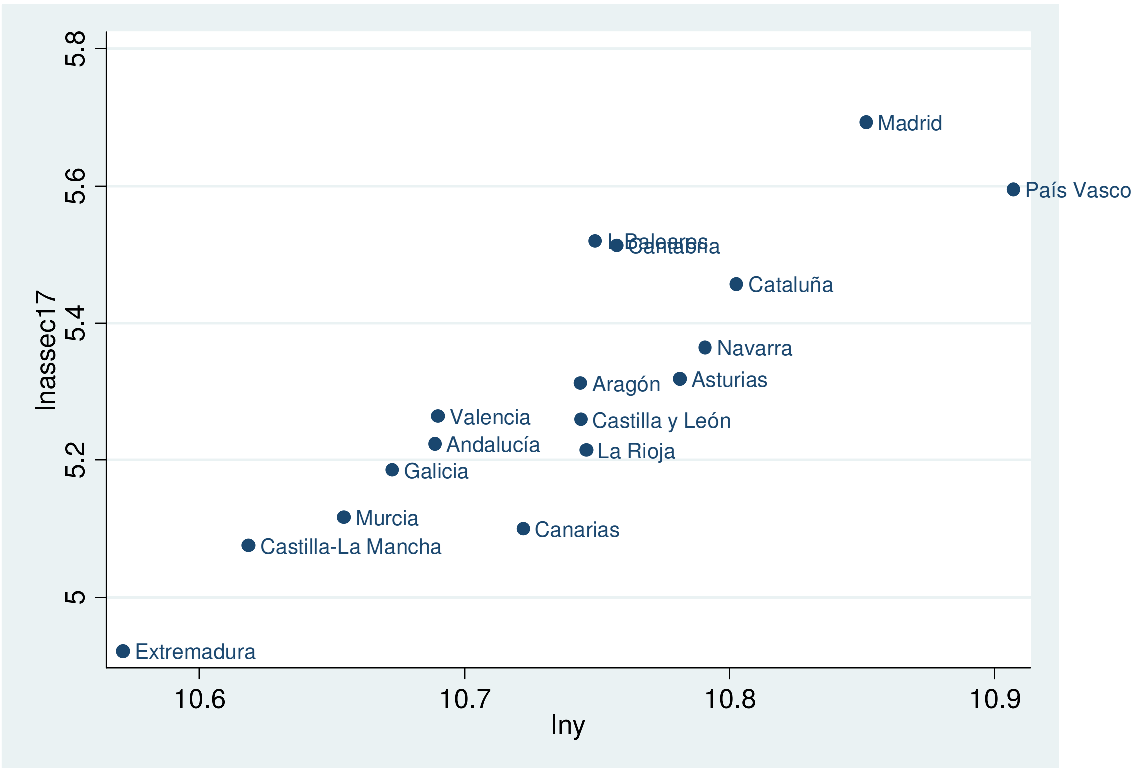


Figure 10: Spanish's Regions Technology Choices (A_u,A_s), 2006

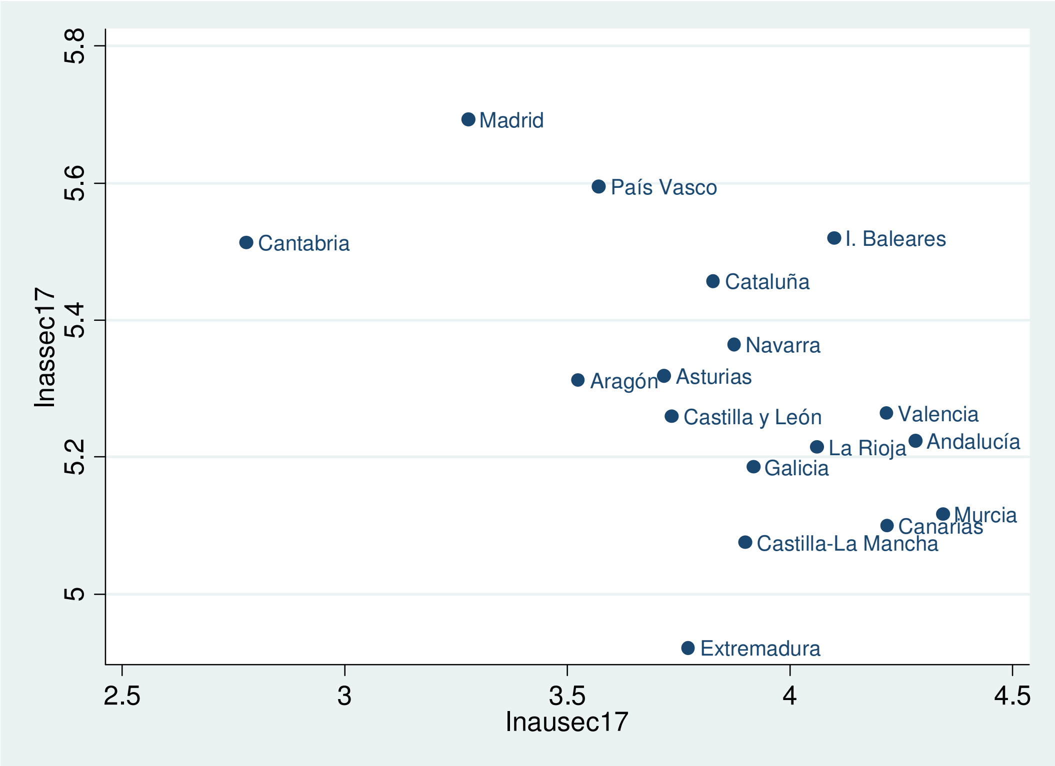


Figure 11: Technology Frontiers of Some Spanish's Regions, 2006

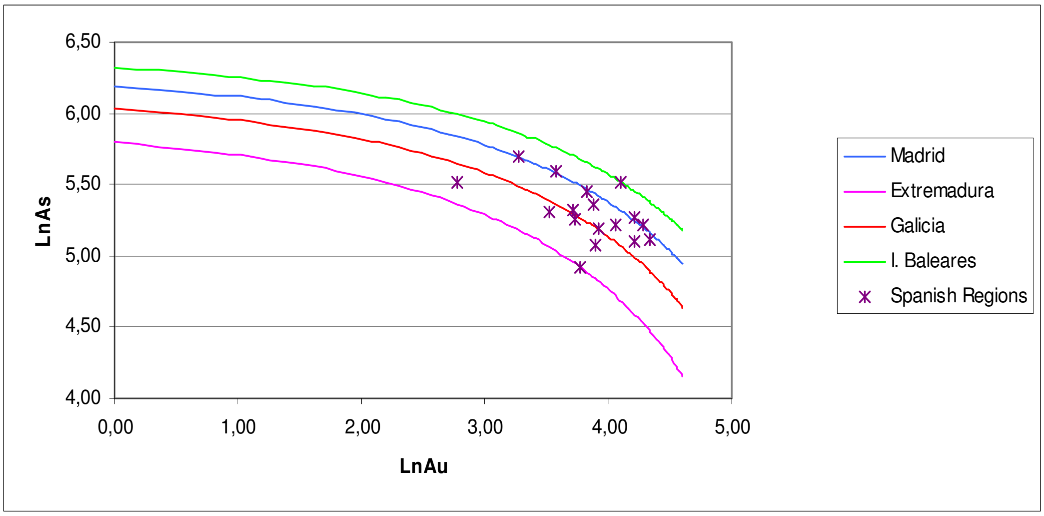


Figure 12: Efficiency of Skilled Labor, Spain 1994-2007

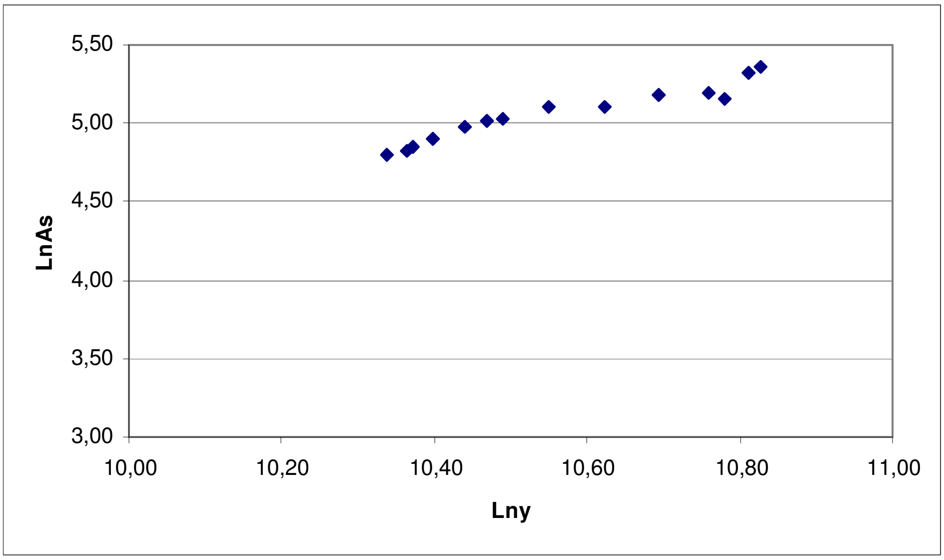


Figure 13: Efficiency of Skilled Labor, Spain 1994-2007

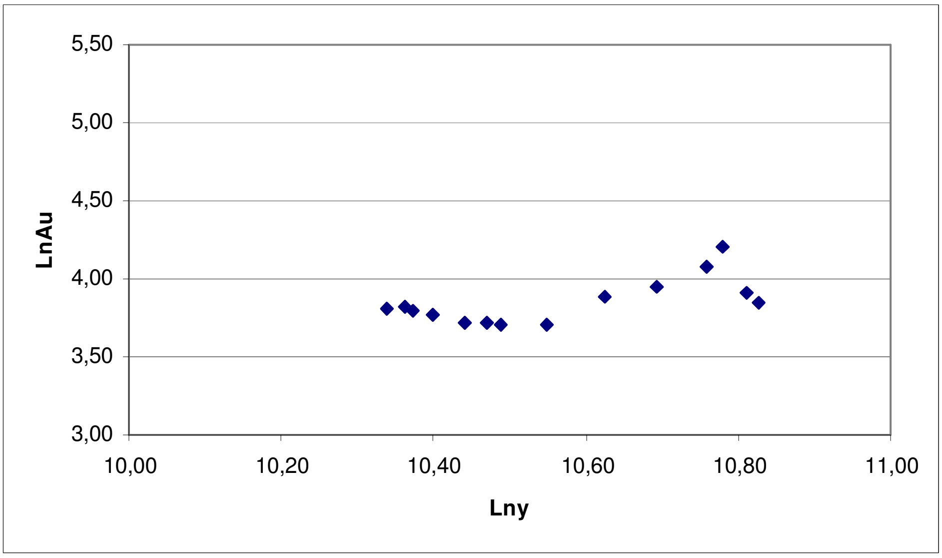


Figure 14: Efficiency of Skilled Labor, Spain 1994-2007 (labelled by year)

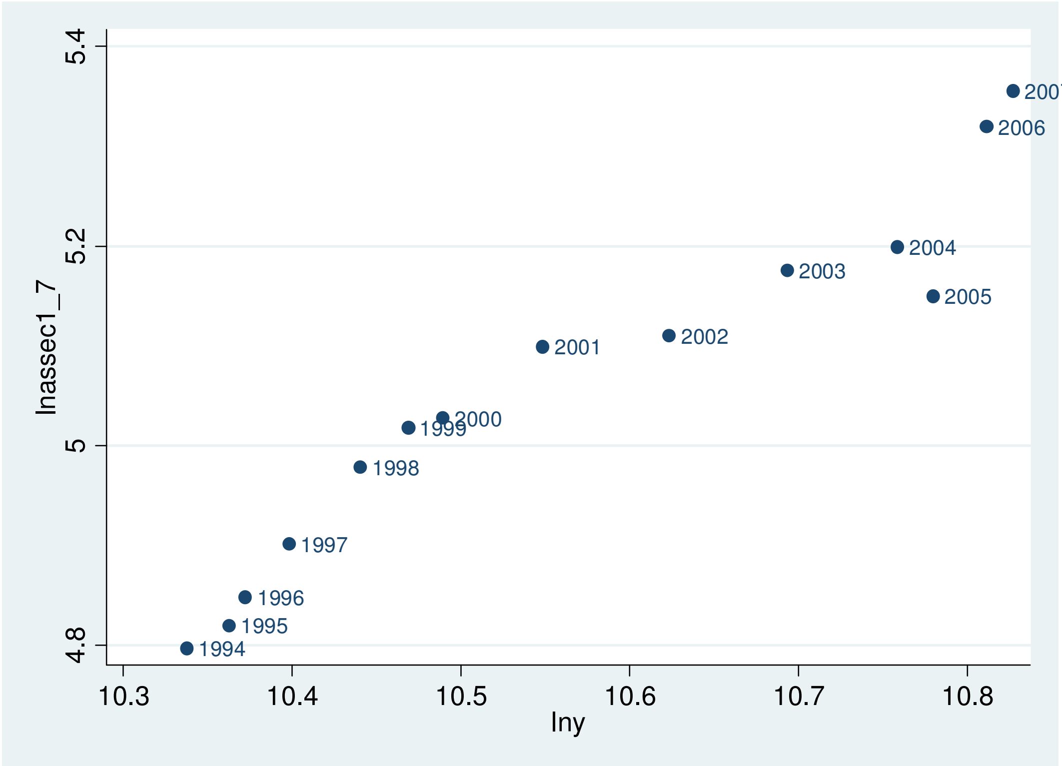


Figure 15: Efficiency of Unskilled Labor, Spain 1994-2007 (labelled by year)

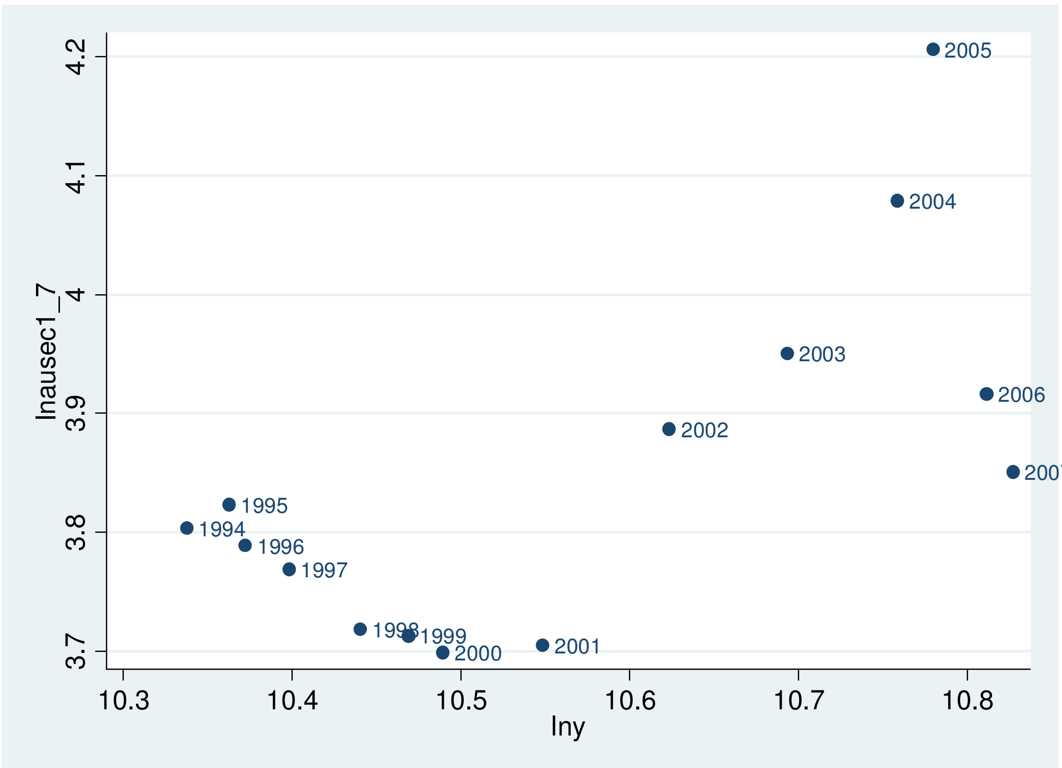


Figure 16: Spanish Technology Choices, 1994-2007

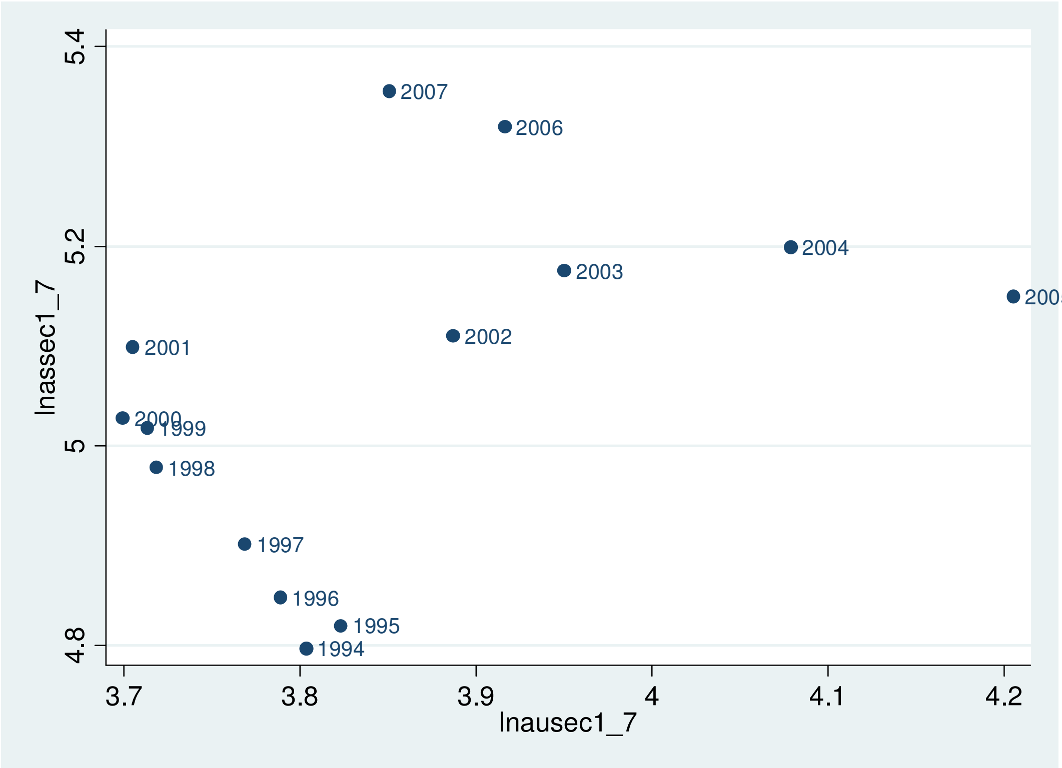


Table 1: Regression Coefficients of *Au* and *As* on *y* (GDP per worker), 2006

	SkillSec						SkillSup					
1/(1-σ)	*As*		*Au*		Dif		*As*		*Au*		Dif	
1.1	3.69	***	-22.45	***	26.15	***	16.75	***	-12.55	***	29.30	***
1.4	3.14	***	-4.58	**	7.72	***	4.75	***	-2.14	**	6.90	***
1.5	2.77	***	-3.39	**	6.17	***	3.96	***	-1.45	*	5.40	***
1.6	2.51	***	-2.60	*	5.11	***	3.42	***	-0.99		4.41	***
1.7	2.16	***	-2.02	*	4.20	***	3.04	***	-0.66		3.70	***
1.9	2.04	***	-1.27		3.32	***	2.53	***	-0.22		2.75	***

Note: *,** y *** statistically significant at levels of 10, 5 y 1%, respectively.

Table 2: Coefficients of Regressions of A_u and A_s on *y*, Spain 1994-2007

		A_u		A_s		*Dif*	
1/(1-σ)	1.1	-2.10	*	2.43	***	4.53	*
	1.4	0.23		1.13	***	0.90	*
	1.5	0.34		1.04	***	0.70	*
	1.6	0.49	**	0.98	***	0.50	
	1.7	0.56	***	0.94	***	0.38	
	1.9	0.66	***	0.89	***	0.23	

Note: *,** y *** statistically significant at levels of 10, 5 y 1% respectively.

APPENDIX

Table A.1: Spain (1994-2007)

			SkillSec			SkillSup		
	y (1)	k (1)	LuSec	LsSec	Ws/WuSec	LuSup	LsSup	Ws/WuSup
1994	30,874	68,420	51.48	48.52	1.56	71.34	28.66	1.67
1995	31,656	70,647	51.50	48.50	1.56	72.24	27.76	1.73
1996	31,962	71,360	50.15	49.85	1.55	70.56	29.44	1.69
1997	32,803	73,433	50.15	49.85	1.60	71.80	28.20	1.78
1998	34,217	75,631	45.76	54.24	1.52	67.49	32.51	1.62
1999	35,197	78,321	45.44	54.56	1.54	65.12	34.88	1.59
2000	35,932	82,597	44.74	55.26	1.53	64.04	35.96	1.58
2001	38,120	87,698	42.36	57.64	1.48	62.66	37.34	1.52
2002	41,091	95,942	42.74	57.26	1.39	61.39	36.07	1.52
2003	44,062	104,186	43.12	56.88	1.41	63.93	34.81	1.48
2004	47,033	112,430	43.50	56.50	1.36	66.46	33.54	1.43
2005	48,040	117,193	45.36	54.64	1.32	67.62	32.38	1.42
2006	49,575	122,656	39.79	60.21	1.40	63.02	36.98	1.47
2007	50,362	126,523	38.54	61.46	1.41	62.33	37.67	1.48

(1) In 2006 euros

Table A.2: Spanish Regions (2006)

				SkillSec			SkillSup		
	Comunidad Autónoma	y	k	LuSec	LsSec	Ws/WuSec	LuSup	LsSup	Ws/WuSup
1	Andalucía	43,865	96,974	49.79	50.21	1.37	71.12	28.88	1.53
2	Aragón	46,346	141,304	32.86	67.14	1.32	65.36	34.64	1.36
3	Asturias	48,111	149,513	39.47	60.53	1.43	66.02	33.98	1.43
4	Islas Baleares	46,599	85,928	44.82	55.18	1.50	70.30	29.70	1.51
5	Canarias	45,356	131,532	50.32	49.68	1.35	75.70	24.30	1.51
6	Cantabria	46,981	133,907	25.29	74.71	1.59	62.28	37.72	1.55
7	Castilla y León	46,348	140,435	36.27	63.73	1.28	62.86	37.14	1.38
8	Castilla-La Mancha	40,886	123,129	47.72	52.28	1.44	67.48	32.52	1.49
9	Cataluña	49,154	119,703	36.58	63.42	1.35	63.51	36.49	1.42
10	Valencia	43,915	94,134	46.08	53.92	1.31	71.18	28.82	1.45
11	Extremadura	38,996	148,493	51.51	48.49	1.55	72.12	27.88	1.68
12	Galicia	43,168	121,773	45.91	54.09	1.44	69.10	30.90	1.51
13	Madrid	51,619	113,194	27.05	72.95	1.46	52.80	47.20	1.55
14	Murcia	42,385	94,741	49.63	50.37	1.26	77.23	22.77	1.40
15	Navarra	48,575	123,271	28.23	71.77	1.02	54.84	45.16	1.25
16	País Vasco	54,561	139,248	26.57	73.43	1.22	45.12	54.88	1.23
17	La Rioja	46,437	123,961	36.00	64.00	1.09	57.93	42.07	1.25

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