# Changes in the skill structure of the labour force. An empirical application to the Spanish case.*

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**Abstract**

Over the past two decades the Spanish economy, as well as many other economies, has known a process of skill upgrading in its labour force. Although many previous studies on this phenomena took as reference *non production workers*, the present study focus on high skilled labour force. Most of the variation in this qualified labour force has been within industries which points to internal reorganization of firms as the origin of this shift. To analyze the impact of physical and technological capital introduction on the wage share of skilled workers, a regression format based on the *translog cost function* has been used. Results show the positive influence that both stocks have had on the share of skilled. Furthermore, they are able to explain by their own most of the observed change in this share.

**Keywords**: Labour demand; Capital-skill complementarity; Ladder effect; Time series.

**Journal of Economic Literature**: C22, E24, J21, .

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# 1 Introduction

The structure of employment and wages has been substantially modified over the two last decades in many O.E.C.D. countries. While the evolution of wages differs considerably among countries (the increase in wage inequalities observed in United States and United Kingdom contrasts with the stability in wage differentials of some European countries as Spain, France, Sweden or Denmark), in the case of employment a common shift towards skilled labour is clearly detected. It is still to be determined whether this shift results from a modification in the economic structure of the country, which may have become specialized in activities being skill intensive (*between industry effect*), or is simply due to a process of internal reorganization of all firms (*within industry effect*) favouring skilled workers. Analyzing the reasons that have stimulated the skill upgrading process, gives a clue about the nature (between or within industry) of the movement. One hypothesis that has received a very large support (Berman, 1994; Machin, 1996; Krusell, 2000) points to the process of capital accumulation as the main reason of the skill upgrading process. New technologies, either disembodied or embodied in the capital stock, have been proved to be skill requiring. Moreover, its adoption has promoted the already mentioned internal reorganization of firms (Aguirregabiria, 2001).

A second hypothesis that has often been invoked concerns international trade (Hansson, 2000), whose effects can go both towards a change in the economic structure of the country and towards an internal reorganization of firms. In this sense, trade with countries having a comparative advantage on unskilled labour intensive industries stimulates specialization on skill intensive industries (between industry effect). On the other side, firms reorganize their activities outsourcing on foreign countries (where labour is cheaper) the less skill requiring tasks of the production process (within industry effect).

A last hypothesis, which has never been mentioned and which is particularly relevant for the Spanish case, concerns job competition. That is, the rise in the proportion of skilled workers would also be due to the fact that they are occupying jobs that traditionally corresponded to unskilled workers (Dolado J., 2002).

The objective of this study is to test the validity of the capital skill complementarity hypothesis on the Spanish data using a translog model similar to that of Berman (1994)(see also Machin (1996)). Spain is an interesting case because of the presence of the *ladder effect* or job competition. This study analyzes to which extent capital accumulation can explain by its own, without considering job competition or other factors, the skill upgrading process of the labour force. The study is done on both, the aggregate and the sectoral level and covers the period 1980-1999. The distinction between physical capital stock and technological capital stock (it embodies technical progress) is also introduced. Both are computed according to a perpetual inventory method (Griliches, 1979) taking as reference the investment on fixed capital for the first type and the investment in tools and material of R&D for the second type. The reason for distinguishing between both kinds of stock is to take into account the possible stronger impact of new technologies in the skill upgrading process specially during the nineties when a great number of innovations were introduced.

Several studies are based on the distinction between white and blue collar workers (or similarly between *non production* and *production* workers). However, as shown in Table 1, defining the skill level in terms of white and blue collars or in terms of education level yields quite different measures of skill changes. During the eighties and, specially during the nineties both the absolute number of skilled workers (defined as individual with university or higher studies degree) and their participation in total employment and in industrial employment, more than doubled. This contrasts with the evolution of white collar workers whose trend was less upward pronounced. By focusing on the level of education instead of the occupations, this study makes a new contribution, since, as data reveals, skill upgrading process has affected all workers.

The remainder of the paper is organized as follows. Section II describes data sources and documents trends in the composition of aggregate employment and industrial employment. A decomposition signaling the importance of internal reorganization of firms in the shift towards skilled labour is also implemented. Section III shows evidence from economy and industrial sector regressions of the effect of various factors on the demand for skilled workers. A discussion about the coefficient accompanying wages is also introduced. Section IV concludes.

| Type of worker | 1980-99 | 1980-89 | 1990-99 |
|---|---|---|---|
| Number of skilled workers in the economy | 197,06% | 50,66% | 74,71% |
| Number of skilled workers in the industrial sector | 153,73% | 31,80% | 66,51% |
| Proportion of skilled workers in the economy | 145,17% | 45,94% | 54,99% |
| Proportion of skilled workers in the industrial sector | 193,10% | 43,23% | 82,91% |
| Number of white collar workers in the economy | 52,76% | 27,04% | 14,77% |
| Number of white collar workers in the industrial sector | 9,52% | -11,02% | 11,88% |
| Proportion of white collar in the economy | 26,52% | 19,35% | 3,83% |
| Proportion of white collar in the industrial sector | 23,34% | -1,17% | 19,16% |

Table 1: Growth rates in the number and proportion of skilled and white collar workers.

# 2 The data.

The research relies on the *Encuesta de Poblacion Activa* (E.P.A) a quarterly survey of the labour market elaborated by the Spanish Statistical National Institute (I.N.E.) since 1964. This survey distinguishes 5 different categories of workers depending on their educational attainments: 1) illiterate or without studies, 2)primary studies, 3)general secondary studies, 4)professional studies and 5)university or higher studies. Regarding professional studies, individuals could access even without having succeed primary education. The duration could be of 2 or 5 years, but since this detailed information was not given, it has been considered as if individuals with professional studies were unskilled. It has been possible to obtain data concerning the degree of education and occupation of workers at the national level. At the industrial level the available information is, on the one side, the degree of education of workers branch by branch and, on the other side, occupations in the total industrial sector.

Information concerning wages comes from the *Encuesta de Salarios en la Industria y los Servicios*. The degree of detail of this data is very reduced. It has been necessary to assume that all skilled workers earn a wage corresponding to an employee level and all unskilled to a manual worker level. Therefore, coefficients associated to wages will have to be analyzed with caution. Finally, the historical series of the other macroeconomic and industrial magnitudes were also obtained from the I.N.E..

Notice that, when dealing with the industrial sector, changes in the classification of the skilled population and, specially, of the activity branches, were made necessary to aggregate into 4 large industries in order to obtain coherent temporary series over the last two decades. As indicator of the production, the Index of Industrial Production (IPI) was used, since there was no information about absolute levels of production for the whole period. The level of disaggregation of the investment in physical capital and in technological capital required a process of summing up in order to make the correspondence between industries and capital stocks.

This paper focuses on people with university or higher studies, whose proportion has followed an increasing tendency. As observed in Table 1, the upward trend accelerated during the nineties when the proportion of skilled moves from 11,69% to 18,12% in the economy (growth rate of 54,99%) and from 5,64% to 10,33% in the industrial sector (growth rate of 82,91%).

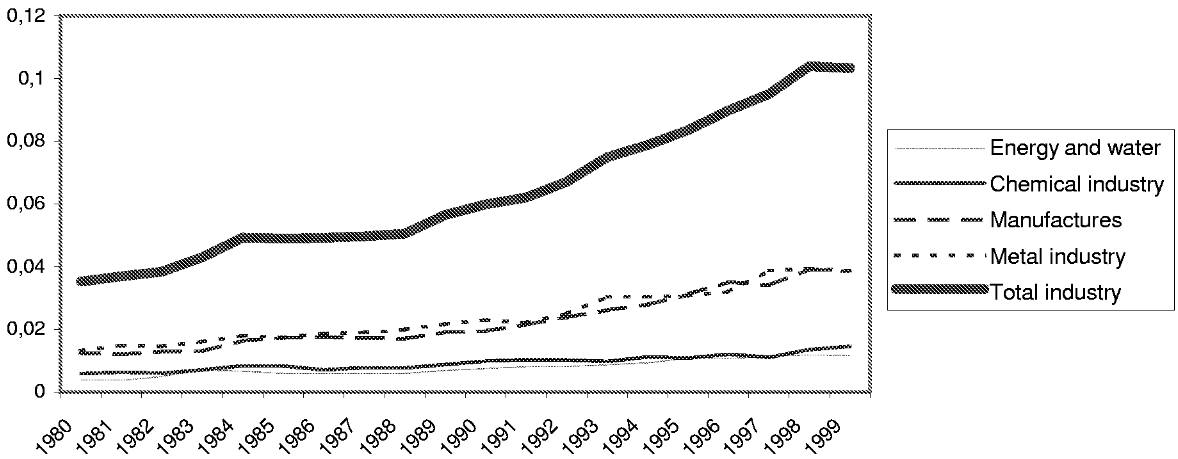


Figure 1: Contribution of each industry to the proportion of skilled in the industrial sector

Among the analyzed industries, chemical and energy are the most skilled labour intensive. This result is not surprising since the manufacture sector covers quite traditional activities not being, in principle, very skill requiring. The metal industry does not only include the innovative activities, but also much more traditional and less skilled labour intensive activities, as metallurgy, which has traditionally been quite important in the Spanish economy. The Spanish industry seems, though, to have lived a *catch up* process and the metal and manufacture industries appear as the main contributors to the increase in the proportion of skilled workers in the industrial sector (Figure 1). The upward trend followed by these two activities contrasts with the stability observed for the chemical and energy industry. Similar results are obtained when the analysis is done in terms of wages shares.

This shift towards a higher skilled labour force can be analyzed with more detail using Berman's (1994) decomposition of the change in the proportion of skilled labour in the economy and industrial sector ($\Delta P_n$):

$$\Delta P_n = \sum_i \Delta M_i \overline{P}_{n_i} + \sum_i \Delta P_{n_i} \overline{M}_i \qquad (1)$$

for $i = 1, 2, ..., N$ economic branches, when (1) is applied to the whole economy, or industries when the equation is applied to the industrial sector. $P_{n_i} = E_{n_i}/E_i$, is the proportion of skilled labour in an activity branch $i$ or in an industry $i$. $M_i = E_i/E$ is the share of employment in the activity branch $i$ or in the industry $i$. A bar over a variable indicates that this one is considered on its mean. The first term on the right of (1) reports the change in the aggregate proportion of skilled attributable to shift in employment shares between activity branches or industries. It implies a modification in the structure of the economy and it is normally attributed to international trade specialization.

The second term in the right of (1) reports the change in the aggregate proportion attributable to changes in the proportion of skilled *within* activity branches or industries. The main hypothesis put forward to explain this effect is the introduction of new production methods that are more skill intensive (biased technological progress). Another explanation used lastly to explain the within effect is related to international trade and more particularly to the process of outsourcing towards developing countries of low skilled requiring tasks.

Table 2 reports the between and within decomposition of the change in the proportion of skilled employment. When dealing with employment it has been possible to disaggregate data concerning the whole economy into 17 economic branches and in the case of the industrial sector, 12 industries have been considered (changes in the industry definition have created some problems). Even if the low level of disaggregation leads to a bias towards the within effect, the global trend and relative importance of each effect is well reflected, and it is not in conflict with studies elaborated for other European cases or Spain (Aguirregabiria, 2001). Similar results can be obtained in terms of wage shares.

Over the whole considered period, 1980-1999, internal reorganization of the firms (within effect) has accounted for all the shift towards skilled labour for both, the whole economy and the industrial sector. Indeed, the between effect has had a negative impact. That is, the restructure of the economic activity would have negatively influenced skilled labour. Since this effect is normally attributed to trade, and Spain opened to international trade during the eighties, it can be thought that Spanish comparative advantages were not on high skilled labour intensive activities but rather on low skilled. The final positive effect on the share of skilled is then explained by the process of internal reorganization of firms during the considered period.

When the attention is focused on changes between cycle peak years 1980-85, 1986-93 and 1994-99 results are less relevant, since they are subject to conjunctural variations. At the aggregate level, the participation in the total change of the within effect is increasing from 52,18% in 1980-85 to 77,39% in 1994-99. At the industrial level, the most remarkable fact is the reduction in the importance of the within effect down to 20,97% during the period 1986-93. This result is reasonable since a great opening to trade of the Spanish economy took place in 1986 with its entry in the European Union. This led to a deep process of restructuring of the Spanish industrial sector, which had been traditionally very protected and which had to face suddenly an increased outside competition. Furthermore, the beginning of the crisis reinforced this process which caused many employment losses and the closure of many firms.

# 3 A translog model

## 3.1 The model

In the previous section it was shown that most of the skill upgrading in the economy and in the industrial sector was explained by within effects. To

| Share of skilled | 1980-99 | 1980-85 | 1986-93 | 1994-99 |
|---|---|---|---|---|
| Total change in the economy | 0,022 | 0,024 | -0.141 | 0,056 |
| Within branches effect | 0,042 | 0,012 | -0,117 | 0,043 |
| Between branches effect | -0,020 | 0,011 | -0,024 | 0,012 |
| Importance of the within effect | 195,67% | 52,18% | 82,74% | 77,39% |
| Total change in the industrial sector | 0,0147 | 0,0026 | -0.0225 | 0,0065 |
| Within industry effect | 0,0214 | 0,0033 | -0,0047 | 0,0056 |
| Between industry effect | -0,0066 | 0,0008 | -0,0178 | 0,0009 |
| Importance of the within effect | 144,76% | 130,49% | 20,97% | 85,72% |

Table 2: Decomposition of changes in skilled employment in the economy and the industrial sector.

explain which factors may have determined this raise in the skilled's share wage bill it seems convenient to use a regression format. A natural approach is to use a cost function and apply then Shepard's lemma in order to obtain the shares on the left hand side of the expression, as a dependent variable.

As it has already been done in previous research (Berman, 1994; Berndt, 1994; Machin, 1996), share equations are derived from a constant returns to scale *translog variable cost function* where the fixed factors are physical and technological capital and the variable factor is labour (skilled and unskilled). Taking fixed factors as given avoids the problem generated by the lack and low quality information about physical and technological capital prices.

Applying Shepard's lemma to the *translog variable cost function* gives the following relationship between the share of skilled labour in the wage bill, $S_i$ (dependent variable), on one side, and $W_{L1}/W_{L2}$ (skill premium), K (physical capital), T (technological capital) and Y (production), on the other side:

$$S_i = \gamma_{L1_i} + \beta_{L1_i,L1_i} \ln \frac{W_{L1_i}}{W_{L2_i}} + \beta_{L1_i,K_i} \ln K_i + \beta_{L1_i,T_i} \ln T_i + \beta_{L1_i,Y_i} \ln Y_i \qquad (2)$$

where, as it has already been signaled in previous studies (Berman, 1994), the coefficient associated to the skill premium will be positive or negative according to whether the elasticity of substitution between skilled and unskilled labour is below or above one. Capital skill complementarity should lead to $\beta_{L1_i,K_i} > 0$ and $\beta_{L1_i,T_i} > 0$. Furthermore, the constant returns to scale (CRS) hypothesis implies that $\beta_{L1_i,L1_i} = -\beta_{L1_i,L2_i}$ and $\beta_{L1_i,K_i} + \beta_{L1_i,T_i} + \beta_{L1_i,Y_i} = 0$.

Estimated regressions are summarized in Table 3. As it could be expected, both kinds of capital, physical and technological, have a positive influence over the share of skilled workers on total cost whether dealing with the economy or the industrial sector. When distinguishing by gender, apart from the men in the chemical and energy industries and the women in the manufacture industry, signs associated to each coefficient do not substantially change with respect to the general case. Moreover, the relative importance of each coefficient is not modified.

Several econometric tests have been implemented in order to ensure the quality of the obtained results. The stationarity of the time series (shares in the cost, relative wages, capital stocks and production) was tested through an Augmented Dickey Fuller test (unit root test). This test was also applied on the residuals obtained from the implemented regressions in order to verify the existence of cointegration. Finally, the likelihood ratio was used to determine the validity of the CRS hypothesis.

Results of these two tests are summarized in Appendix B. Regarding the unit root tests, the time series of physical capital appears systematically non stationary whether the economy or the industrial sectors are considered. The evolution of technological capital appears non stationary for the economy and the chemical industry. Finally, it is observed the non stationarity of the output at the aggregate level, and of the skill premium and male's share on the wage bill at the metal industry. The presence of time series not being I(1) does not imply that the computed relations between variables will be spurious. It is possible that the series cointegrate establishing a long run relation between them. In this sense, for every implemented regression, an augmented Dickey Fuller (ADF) test is applied to the residuals, to verify their stationarity.

The likelihood ratio confirms that the CRS hypothesis cannot be rejected when dealing with industrial sectors individually, while when the whole economy is concerned the CRS assumption is not accepted. This result is quite surprising, since in other studies this hypothesis has been shown to be realistic. However, it does not put a problem for the present work because of the

| Shares in the cost | Activity | $\gamma_{L1}$ | Ln($W_{L_1}/W_{L_2}$) | Ln K/Y | Ln T/Y | $R^2$ | ADF(1) |
|---|---|---|---|---|---|---|---|
| Skilled workers | Economy | 0,341 | 0,692 | 0,190 | 0,049 | 0,851 | -2,328* |
| | t-stat | (1,534) | (2,162) | (1,948) | (3,245) | | |
| | Chemical industry | -2,101 | 0,392 | 0,221 | 0,062 | 0,820 | -3,044** |
| | t-stat | (-7,035) | (1,940) | (4,858) | (1,869) | | |
| | Metal industry | -0,546 | 0,300 | 0,047 | 0,015 | 0,965 | -3,986** |
| | t-stat | (-11,122) | (12,030) | (9,034) | (4,246) | | |
| | Manufacture industry | -0,460 | -0,118 | 0,021 | 0,081 | 0,947 | -2,476* |
| | t-stat | (-2,804) | (-1,046) | (1,079) | (5,602) | | |
| | Energy industry | 3,556 | 0,288 | -0,359 | 0,035 | 0,887 | -6,141** |
| | t-stat | (6,277) | (1,581) | (-6,322) | (6,083) | | |
| Skilled women | Economy | 0,219 | 0,362 | 0,147 | 0,028 | 0,811 | -2,494* |
| | t-stat | (1,651) | (1,906) | (2,531) | (3,077) | | |
| | Chemical industry | -1,407 | 0,081 | 0,145 | 0,026 | 0,930 | -4,235** |
| | t-stat | (-10,461) | (1,803) | (9,265) | (2,288) | | |
| | Metal industry | -0,189 | 0,086 | 0,016 | 0,002 | 0,940 | -4,999** |
| | t-stat | (-10,078) | (8,995) | (8,298) | (1,759) | | |
| | Manufacture industry | 0,015 | -0,095 | -0,016 | 0,043 | 0,917 | -4,547** |
| | t-stat | (0,232) | (-2,223) | (-1,924) | (6,215) | | |
| | Energy industry | 0,492 | 0,120 | -0,050 | 0,003 | 0,748 | -4,953** |
| | t-stat | (1,840) | (1,957) | (-1,907) | (1,170) | | |
| Skilled men | Economy | 0,127 | 0,327 | 0,039 | 0,021 | 0,804 | -2,692* |
| | t-stat | (1,394) | (2,491) | (0,980) | (3,468) | | |
| | Chemical industry | 0,879 | 1,021 | -0,110 | 0,011 | 0,850 | -4,466** |
| | t-stat | (5,143) | (9,683) | (-4,984) | (0,968) | | |
| | Metal industry | -0,250 | 0,227 | 0,016 | 0,016 | 0,951 | -4,447** |
| | t-stat | (-6,055) | (10,794) | (3,771) | (5,338) | | |
| | Manufacture industry | -0,142 | -0,046 | 0,002 | 0,039 | 0,919 | -3,235** |
| | t-stat | (-1,555) | (-0,728) | (0,247) | (4,885) | | |
| | Energy industry | -0,834 | 0,893 | 0,084 | -0,004 | 0,976 | -4,844** |
| | t-stat | (-3,297) | (15,320) | (3,377) | (-1,514) | | |

Table 3: Skilled worker's share in the wage bill of the economy and the industrial sector.

(*) Significant at 5%. (**) Significant at 1%.

existence of cointegration in the regressions.

### 3.2 Capital-skill complementarity

Both, physical and technological capital have positively yielded the evolution of the wage share of skilled on total cost. Furthermore, apart from the energy industry, where a process of substitution of physical capital by technological capital seems to have taken place, investment on both types of capital has favoured the skill upgrading process. New technologies do not appear as having a permanent dominant role as it could have been expected given that the analyzed period includes the nineties.

The values of the coefficients associated to K and T give information about the sense of the impact that these variables have had over the share of skilled between 1980-1999. However, in order to determine the importance of this impact it is necessary to take into account not only the size of the coefficients but also the increase in the stocks of K and T. Given the CRS assumption, we can suppose a simultaneous change in $K/Y$ and $T/Y$ in equation (2), accompanied by a change in relative wages too:

$$\Delta S_i = \beta_{L1_i,L1_i} \Delta \ln \frac{W_{L1_i}}{W_{L2_i}} + \beta_{L1_i,\frac{K_i}{Y_i}} \Delta \ln \frac{K_i}{Y_i} + \beta_{L1_i,\frac{T_i}{Y_i}} \Delta \ln \frac{T_i}{Y_i} \tag{3}$$

The estimated change in the share of skilled on the total cost when considering the effects of the variations of $\ln \frac{K_i}{Y_i}$, $\ln \frac{T_i}{Y_i}$ and $\ln \frac{W_{L1_i}}{W_{L2_i}}$ are displayed on Table 4. The main results can be summarized as follows:

- At the aggregate level, the annual growth rates of $K/Y$ and $T/Y$ have respectively been 0,68% and 6,30%. The larger growth of technological capital compensates its low coefficient and, indeed, the raise in the share of skilled workers is considerably driven by it. Therefore, the skill biased technological progress seems to be at the origin of the skill upgrading in the workers. This statement also holds when the distinction between women and men is made.

- Regarding the chemical industry, the annual growth rates of $K/Y$ and $T/Y$ have been 2,2% and 3,4%, respectively. The larger coefficient associated to K determines however a more important impact of the physical capital than of the technological capital. That is, the role of embodied technical progress in promoting skill upgrading of the labour force, in this industry, is smaller than that related to physical capital accumulation.

- The metal industry is the one to have suffered a skill biased technological change. This industry concentrates all branches qualified by the National Statistic Institute as being of *high and medium technology*, i.e. electric, electronic and mechanical machinery, precision tool, optics, transport material. This industry also includes metallurgy, a traditional activity being very intensive in physical capital and which still remains an important activity inside the Spanish industry.

  The higher coefficient associate to K implies that the effects of $K/Y$ and $T/Y$ do not differ much when dealing with all workers, even if their annual growth rates do, being 2,1% and 6,5%, respectively. The situation is modified when distinguishing between women and men. While for the latter the effect of technological capital is 3 times larger than that of physical capital, in the women's case, the impact of $K/Y$ is more than twice larger than that of $T/Y$. Men in the metal industry have benefited more from the internal reorganization that seems to have been implemented through the introduction of new technologies. This gives on idea about the different types of positions occupied by men and women in this sector.

- Manufacture industry refers to what it has been generally called *traditional industries*, that is: food, drink, tobacco, textiles, leather, wood, paper, etc. The analysis of these activities is interesting since they have suffered the most important part of the restructuring process lived by the industrial sector during the late eighties and the beginning of the nineties. As a result only the most competitive activities survived. Although lots of jobs were destroyed during this adaptation period, the proportion of skilled workers in the manufacture industry kept increasing, suggesting that restructuring mainly damage unskilled labour. This also points to the possibility that the restructuring implied either an internal reorganization of firms favouring skilled workers or an introduction of capital (physical or technological) being unskilled labour saving.

In the manufacture sector the annual growth rates of $K/Y$ and $T/Y$ have been 2,2% and 6,0%, respectively. Furthermore, coefficients associated to T are larger than those accompanying K. It is then not surprising to find that new technologies are the clear determinant of the shift towards skilled labour whether the analysis concerns total workers, men or women.

- The energy industry covers all the activities related to production and distribution of energy, depuration of water, extraction and treatment of oil, etc. In this case it seems that the combined reduction of $K/Y$, which has declined at an annual rate of 0,5%, and an increase in $T/Y$ (whose annual rate has been of 12,3%) is at the origin of the skill upgrading process in the labour force.

The following step will now be to compare the change in the skilled shares predicted by the model used in this work with the observed change of this share. Table 5 shows how in most cases the evolution of the share of skilled workers is mainly explained by the evolution of the factors here considered, that is, capital accumulation, technological change and relative wages. It can, therefore, be concluded that despite not taking into account the *ladder effect* the model presented in this work is able to explain most of the observed change in the skilled's share. When distinguishing by gender, results are less satisfactory. An overestimation is found for the metal and manufacture industries and for the energy industry case, the model is able to predict less than 50% of the observed change in the share of skilled workers.

## 3.3 Relative wages: A brief discussion

As it was pointed at the beginning of section 3, the coeffcient associated to the skill premium will be positive or negative depending on whether the elasticity of substitution between skilled and unskilled workers is below or above one. It has been shown (Uzawa, 1962) that Allen partial elasticities of

| Share in total cost | Activity | $\Delta S$ | $\beta_{L1,L1}\Delta \ln \frac{W_{L1}}{W_{L2}}$ | $\beta_{L1,K}\Delta \ln \frac{K}{Y}$ | $\beta_{L1,T}\Delta \ln \frac{T}{Y}$ |
|---|---|---|---|---|---|
| $\Delta$ Skilled workers | Economy | 0,1364 | 0,0479 | 0,0256 | 0,0629 |
| | Chemical industry | 0,1534 | 0,0232 | 0,0912 | 0,0390 |
| | Metal industry | 0,0998 | 0,0631 | 0,0186 | 0,0180 |
| | Manufacture industry (*),(**) | 0,0914 | -0,0060 | 0,0087 | 0,0887 |
| | Energy industry (*) | 0,1288 | 0,0119 | 0,0399 | 0,0770 |
| $\Delta$ Skilled women | Economy | 0,0808 | 0,0251 | 0,0198 | 0,0359 |
| | Chemical industry | 0,0810 | 0,0048 | 0,0598 | 0,0164 |
| | Metal industry | 0,0268 | 0,0181 | 0,0063 | 0,0024 |
| | Manufacture industry | 0,0356 | -0,0048 | -0,0069 | 0,0473 |
| | Energy industry (***) | 0,0171 | 0,0050 | 0,0056 | 0,0066 |
| $\Delta$ Skilled men | Economy (**) | 0,0548 | 0,0226 | 0,0053 | 0,0269 |
| | Chemical industry (***) | 0,0218 | 0,0603 | -0,0454 | 0,0069 |
| | Metal industry | 0,0733 | 0,0478 | 0,0063 | 0,0192 |
| | Manufacture industry (*),(**) | 0,0420 | -0,0023 | 0,0011 | 0,0432 |
| | Energy industry (***) | 0,0189 | 0,0370 | -0,0093 | -0,0088 |

Table 4: Contribution of each factor to the change in the wage share on total cost.

(*) $\beta_{L1,L1}$ non significant. (**) $\beta_{L1,K}$ non significant. (* * *) $\beta_{L1,T}$ non significant.

| Share in total cost | Activity | $\Delta S_i$ estimated | $\Delta S_i$ observed | Percentage |
|---|---|---|---|---|
| $\Delta$ Skilled workers | Economy | 0,1364 | 0,1511 | 90,26% |
| | Chemical industry | 0,1533 | 0,1939 | 69,09% |
| | Metal industry | 0,0997 | 0,0900 | 110,77% |
| | Manufacture industry (*),(**) | 0,0913 | 0,0942 | 96,95% |
| | Energy industry (*) | 0,1288 | 0,1473 | 87,41% |
| $\Delta$ Skilled women | Economy | 0,0808 | 0,0857 | 94,22% |
| | Chemical industry | 0,0809 | 0,0812 | 99,72% |
| | Metal industry | 0,0268 | 0,0263 | 101,73% |
| | Manufacture industry | 0,0356 | 0,0338 | 105,11% |
| | Energy industry (***) | 0,0171 | 0,0348 | 49,10% |
| $\Delta$ Skilled men | Economy (**) | 0,0550 | 0,0648 | 84,59% |
| | Chemical industry (***) | 0,0218 | 0,1124 | 19,42% |
| | Metal industry | 0,0733 | 0,0635 | 115,39% |
| | Manufacture industry (*),(**) | 0,0420 | 0,0416 | 101,03% |
| | Energy industry (***) | 0,0189 | 0,1063 | 17,79% |

Table 5: Comparison between the real change of the wage shares between 1980-1999 and the predicted change by the model.

(*) $\beta_{L1,L1}$ non significant. (**) $\beta_{L1,K}$ non significant. (***) $\beta_{L1,T}$ non significant.

substitution (AES) between two inputs i and j can be obtained from a cost function through the following formula:

$$\sigma_{ij} = \frac{C * C_{ij}}{C_i * C_j} \tag{4}$$

where $C_i = \frac{\delta C}{\delta P_i}$, $C_{ij} = \frac{\delta C}{\delta P_i * \delta P_j}$ and by definition $\sigma_{ij} = \sigma_{ji}$. For the particular kind of function used on this paper the AES are:

$$\sigma_{i,j} = 1 + \frac{\beta_{i,j}}{S_i * S_j} \tag{5}$$

where i, j=L1, L2 and homogeneity on prices implies $\beta_{L_i,L_i} = -\beta_{L_i,L_j}$ for $j \neq i$. The price elasticity of demand for factors of production, $E_{ij}(E_{ij} = \frac{\delta L_i}{\delta w_j})$ has been proved (Allen, 1938) to be analytically related to the AES:

$$E_{ij} = \sigma_{ij} * S_j \tag{6}$$

Therefore, even though $\sigma_{ij} = \sigma_{ji}$, in general $E_{ij} \neq E_{ji}$. For the translog function this expression becomes:

$$E_{i,j} = S_j + \frac{\beta_{i,j}}{S_i} \tag{7}$$

Many of the previous empirical studies in the literature give the AES the most prominent role when measuring substitution. These approaches have been however criticized (Blackorby, 1989) in the sense that *the AES has no meaning as a quantitative measure and, qualitatively, it does not add any additional information to that contained in the cross-price elasticity.*

Even if in this work both types of elasticities are computed, it is interesting to pay attention to equation (7). As it has already been noticed in the literature (Schmidt, 2001), $E_{ij}$ should tend to be the closer to the cost share $S_j$ the larger is the cost share $S_i$. Indeed, the larger the cost share $S_i$ of factor i already is, the harder it is to substitute i for a factor j whose price is increasing, and input reactions of i depend on the cost share $S_j$. A problem that is likely to be found then in the present study, is linked to the fact that only two factors are considered when computing the variable cost, $L1$ and

$L2$. Therefore, their shares in this cost are very big, and this will make it difficult to substitute them.

On the other hand, in a world with only two variable factors, it will not make sense to find a negative elasticity, ie. absolute complementarity between factors. Furthermore, in principle, the elasticities for the whole economy and the industrial sector (except from the manufacture industry) should be below one, because the $\beta_{L1,L2}$ are positive. Therefore, $\sigma_{L1,L2}$ should be between 0 and 1 (weak substitutability).

In Table 6 the AES and cross-price elasticities of substitution are computed for the economy and the different industrial sectors. When considering all skilled workers the only positive elasticity corresponds to the manufacture industry, and, it is actually bigger than one. This same problem appears in the skilled men's case, while in the women's case elasticities are positive when referring to all industries. Furthermore, they are below one for the chemical, energy and metal industries.

Several reasons could be at the origin of the unsatisfactory values found for the elasticities:

- Evidently, there can be data problems, since, specially regarding wages, the information was not detailed enough.

- It must also be taken into account that the negative values obtained for the elasticities, are punctual estimations. The confidence interval could go from this negative value to a positive value, leaving open the possibility of weak substitutability between factors. However, due to the fact that $S_{L1}$ and $S_{L2}$ depend on $\beta_{L1,L2}$ testing this hypothesis becomes extremely complicated[1].

- It is well known in the econometric literature (Hamermesh, 1979) that elasticity estimates obtained from a cost share based in a translog cost function have large standard errors. This could explain why, for example, $E_{L1,L2} = S_{L2} - \frac{\beta_{L1,L2}}{S_{L1}}$ is so far away from $S_{L2}$ while, as noticed before, it should be closer due to the large value of $S_{L1}$.

[1]Because of this dependence, applying the usual $tstat = \frac{\beta_{L1,L2} - S_{L1} * S_{L2}}{std.dev.\beta_{L1,L2}}$ would be incorrect

- It can also be proved (Appendix D) that by ignoring the fact that skilled workers are also occupying complex jobs (*ladder effect*), the $\beta_{L1,L2}$ is overestimated, leading to negative values for the elasticity.

Having identified different possible origins of the unsatisfactory results, the following step would be to try to improve them. Since regarding the three first reasons, there is not much to do, it is interesting to focus on the possibility of taking into account the *ladder effect*. Total differentiation (Appendix D equation (20)) can be interpreted as a way of log-linearize, where the coefficients of the explanatory variables can be assumed to be constant (evidently, this proxy will be more or less correct depending on the evolution of $\lambda$[2] and $\pi_1$[3]). Using (20) and taking into account the fact that $\frac{d\lambda}{\lambda}$ and $\frac{d\pi_1}{\pi_1}$ are accompanied coefficients only differing in the sign, it can be suggested a new reformulation of the estimated equation, (2),

$$S_i = \gamma_{L1_i} + \beta_{L1_i,L2_i} \ln \frac{W_{L1_i}}{W_{L2_i}} + \beta_{L1_i,K_i} \ln K_i + \beta_{L1_i,T_i} \ln T_i + \beta_{L1_i,Y_i} \ln Y_i + \beta_{\lambda,\pi_1} \ln \lambda - \beta_{\lambda,\pi_1} \ln \pi_1 \tag{8}$$

Results from the estimation are summarized in Table 11 of Appendix C. As it can be seen, the OLS estimations are not improved by the introduction of the term that proxies the fact that some skilled are not in complex jobs but in simple, and therefore earn a lower wage.

# 4 Conclusions

Since 1980 the Spanish economy has lived a process of skill upgrading in its labour force. Today, 18,12% of the labour force is skilled and their share in the cost amounts to more than 21%. This phenomena is not unique to Spain, in most of O.C.D.E countries it has also been observed. Many of the previous studies were based on the distinction between *production workers* and *non production workers*. They made the equivalence between *non production workers* and skilled workers. In this work, the analysis has

[2] Proportion of skilled in simple jobs(*ladder effect*)

[3] $\pi_1 = \frac{L1}{L1+L2}$

| Type of worker | Activity | $\sigma_{L1,L2}$ | $E_{L1,L2}$ |
|---|---|---|---|
| Skilled workers | Economy | -4,055 | -3,388 |
| | Chemical industry | -1,386 | -1,102 |
| | Energy industry | -1,298 | -1,113 |
| | Manufacture industry | 3,134 | 2,937 |
| | Metal industry | -2,504 | -2,272 |
| Skilled women | Economy | -1,644 | -1,379 |
| | Chemical industry | 0,507 | 0,388 |
| | Energy industry | 0,043 | 0,028 |
| | Manufacture industry | 2,766 | 2,599 |
| | Metal industry | 0,016 | 0,007 |
| Skilled men | Economy | -1,388 | -1,166 |
| | Chemical industry | -5,211 | -4,112 |
| | Energy industry | -6,115 | -5,210 |
| | Manufacture industry | 1,855 | 1,741 |
| | Metal industry | -1,596 | -1,447 |

Table 6: AES and cross-price elasticities of substitution between skilled and unskilled workers

explicitly focused on skilled people, since it has been shown that the process of skill upgrading has concerned both *production workers* and *non production workers*.

The procedure of analysis is inspired on Berman et al.(1994). First, the total change in the skilled labour force is divided into the *between effect*, normally attributed to a modification in the structure of the economy, and the *within effect*, reflecting an internal reorganization of the economic activities. Once verified that, in concordance with many previous studies of other countries, the within effect explains most of the skill upgrading process in Spain over the period 1980-1999, the following step was to prove the impact of capital accumulation on the share of skilled. A *translog variable cost function* distinguishing between physical and technological capital was defined. Using Shepard's lemma it was the possible to obtain the share of skilled on total cost as a dependent variable of an equation having as explicative variables: the skill premium, production and the stock of physical and technological capital.

The implemented OLS regressions show that the introduction of both new technologies and physical capital, is at the origin of the skill upgrading process in the labour force. The only activity for which statement does not apply is the energy industry, where physical capital seems to have been replaced by technological capital.

On the other hand, a proxy of the *ladder effect* was introduced in the regressions in order to solve the puzzling results obtained for the elasticities of substitution between skilled and unskilled. This essays were not satisfactory, which permits to deduce that data problems (particularly with wages) or/and the type of cost function assumed (the static translog approach might not be as that flexible) may be at the origin of the problems.

## Appendix A: Tables

| | 1981-99 | 1981-89 | 1990-99 |
|---|---|---|---|
| Skilled white collars in the economy | 138,13% | 53,56% | 50,49% |
| Skilled workers in the economy | 144,18% | 58,52% | 49,56% |
| Skilled workers in energy and water industry | 171,06% | 66,94% | 55,13% |
| Skilled workers in chemical industry | 143,56% | 53,95% | 41,48% |
| Skilled workers in manufacture industry | 285,45% | 72,13% | 120,11% |
| Skilled workers in metal industry | 144,50% | 50,68% | 53,10% |
| Skilled workers in the industry (average) | 166,03% | 58,74% | 55,84% |

Table 7: Growth rates in the wage bill of skilled workers.

## Appendix B: Econometric tests

| Likelihood Ratio | Sk | Skwc | Skw | Skm |
|---|---|---|---|---|
| Economy | 10,36** | 11,50** | 39,52** | 30,72** |
| Chemical industry | 17,30** | | 2,68 | 0,86 |
| Metal industry | 6,32* | | 8,28** | 4,88* |
| Manufacture industry | 1,28 | | 1,86 | 0,008 |
| Energy industry | 3,04 | | 0,10 | 0,22 |

Table 8: Likelihood ratio test ($H_0 : CRS$).

Sk and Skwc are the shares of skilled and skilled white collar workers on total cost. Skw is the share of skilled women on total cost. Skm is the share of skilled men on total cost.
(*) Significant at 5%. (**) Significant at 1%.

| Unit root test | | | | | | | |
|---|---|---|---|---|---|---|---|
| Economy | Sk, Skwc | Skw | Skm | $\frac{W_{L_1}}{W_{L_2}}$ | K | Ktec | Y |
| Dickey Fuller | -5,09**, -4,38* | -5,42** | -4,27* | -3,31* | -1,27 | 1,90 | 2,18 |
| Chemical ind. | Sk | Skw | Skm | $\frac{W_{L_1}}{W_{L_2}}$ | K | Ktec | Y |
| Dickey Fuller | -5,83** | -3,87* | -4,88** | -4,86** | -1,51 | -1,81 | -4,25** |
| Metal ind. | Sk | Skw | Skm | $\frac{W_{L_1}}{W_{L_2}}$ | K | Ktec | Y |
| Dickey Fuller | -4,66** | -4,78** | -2,92 | -2,88 | -1,56 | -3,19* | -3,98** |
| Manufacture ind. | Sk | Skw | Skm | $\frac{W_{L_1}}{W_{L_2}}$ | K | Ktec | Y |
| Dickey Fuller | -5,83** | -5,49** | -4,01** | -5,82** | -1,43 | -3,61* | -3,64* |
| Energy ind. | Sk | Skw | Skm | $\frac{W_{L_1}}{W_{L_2}}$ | K | Ktec | Y |
| Dickey Fuller | -3,75* | -4,69** | -3,77* | -4,35** | -3,51 | -5,24** | -3,49* |

Table 9: Unit Root test.

To analyze the stationarity of the variables, each time series is put in logarithms. A unit root test (augmented Dickey Fuller[4]) including two lags

[4]The null hypothesis of this test is existence of a unit root (non stationarity). Other tests take as a null the hypothesis of stationarity (Philips-Perron) but since they create some problems it has been decided to use the traditional Dickey Fuller test.

of the differentiated variable, a constant and a trend is applied. In a next step, the significance of the trend is analyzed, keeping it in the test if it is significant or eliminating it on the opposite case. Then non significant lags are successively eliminated.

On the other hand, the likelihood ratio was applied to verify the convenience of the hypothesis of CRS[5].

[5]Notice that, due to the reduced size of the sample, the likelihood ratio will have a low reliability since its distribution will not be exactly a chi squared.

## Appendix C: Skilled white collar workers and robustness

| Share in the cost | Activity | C | Ln($W_{L1}/W_{L2}$) | Ln K/Y | Ln T/Y | $R^2$ | ADF |
|---|---|---|---|---|---|---|---|
| Skilled white collars workers | Economy | 0,326 | 1,378 | 0,111 | 0,063 | 0,908 | -2,638* |
| | t-stat | (5,566) | (7,853) | (2,024) | (10,393) | | |

Table 10: Skilled white collar worker's wage share in total cost.

| Share in wage bill | Constant | Ln$W_{L1}/W_{L2}$ | Ln K | Ln T | Ln Y | Ln $\lambda$ | Ln $\frac{\lambda}{\pi_1}$ |
|---|---|---|---|---|---|---|---|
| Skilled workers | 0,426 | 0,387 | 0,072 | -0,034 | -0,037 | 0,114 | |
| t-stat | (2,831) | (1,748) | (1,057) | (-2,079) | (-0,534) | (6,365) | |
| $R^2$=0,909 ADF=-2,567 | | | | | | | |
| Skilled workers | 0,331 | 0,701 | 0,193 | 0,053 | -0,245 | | -0,011 |
| t-stat | (1,450) | (2,151) | (1,939) | (2,713) | (-2,546) | | (-0,313) |
| $R^2$=0,794 ADF=-2,194 | | | | | | | |

Table 11: Skilled worker's share in the wage bill of the economy taking into account the ladder effect.

**Appendix D: The impact of the *ladder effect* on the elasticity: overestimation of $\beta_{L1,L2}$**

When the firm minimizes costs, the choice it makes in terms of factors is, indeed, between complex and simple jobs, and not between skilled and unskilled workers. In this case, when applying Shepard's lemma, the dependent variable would be the share represented by the cost of complex jobs in the total cost, that is:

$$\alpha^* = \frac{W_1 * NC}{W_1 * NC + W_2 * NS} = \frac{\omega * n}{\omega * n + 1} \tag{9}$$

where NC and NS represent complex and simple jobs, $W_1$ and $W_2$ the corresponding wages, $\alpha^*$ the share of complex jobs in the total cost, $n = NC/NS$ and $\omega = W_1/W_2$. It follows:

$$1 - \alpha^* = \frac{1}{\omega * n + 1} \tag{10}$$

and

$$\frac{\alpha^*}{1 - \alpha^*} = \omega * n \tag{11}$$

In the present study, the choice between simple and complex jobs has been proxy by a choice between skilled and unskilled workers, since the objective was to analyze the process of skill upgrading-which has affected both, *production* and *nonproduction* workers-in the Spanish economy. A problem arises with this proxy since it assumes that all skilled are in complex jobs and therefore earn $W_1$. Therefore, it does not consider the fact that some skilled workers are occupying simple jobs (*ladder effect*).

The estimated share in this work is:

$$\overline{\alpha} = \frac{W_1 * L1}{W_1 * L1 + W_2 * L2} = \frac{\omega * \overline{n}}{\omega * \overline{n} + 1} \tag{12}$$

where $L1$ and $L2$ represent skilled and unskilled workers and $\overline{n} = \frac{L1}{L2}$. It is easy to verify that,

$$1 - \overline{\alpha} = \frac{1}{\omega * \overline{n} + 1} \tag{13}$$

and

$$\frac{\overline{\alpha}}{1-\overline{\alpha}} = \omega * \overline{n} \tag{14}$$

The number of skilled and unskilled workers is, indeed, given by:
$L1 = NC + \lambda * NS$ and $L2 = NS - \lambda * NS$
where it follows that:
$NC = L1 - \frac{\lambda}{1-\lambda} * L2$ and $NS = \frac{1}{1-\lambda} * L2$
then

$$n = \overline{n} - \lambda(1+\overline{n}) \tag{15}$$

Let's call $\pi_1$ to the part of skilled on total employment:

$$\pi_1 = \frac{L1}{L1+L2} = \frac{\overline{n}}{1+\overline{n}} \tag{16}$$

Combining these expressions, it is possible to obtain the following relation between $\alpha*$ and $\overline{\alpha}$:

$$\frac{\overline{\alpha}}{1-\overline{\alpha}} = \frac{\alpha^*}{1-\alpha^*} * \frac{L1}{L2} * \frac{NS}{NC} = \frac{\alpha^*}{1-\alpha^*} * \frac{\pi_1}{\pi_1 - \lambda} \tag{17}$$

By totally differentiating:

$$\frac{\mathrm{d}\overline{\alpha}}{\overline{\alpha}(1-\overline{\alpha})} = \frac{\mathrm{d}\alpha^*}{\alpha^*(1-\alpha^*)} + \frac{\mathrm{d}\lambda}{\pi_1 - \lambda} - \frac{\lambda}{\pi_1 - \lambda} * \mathrm{d}\pi_1 \tag{18}$$

where it follows:

$$\mathrm{d}\overline{\alpha} = \frac{\overline{\alpha}(1-\overline{\alpha})}{\alpha^*(1-\alpha^*)} * \mathrm{d}\alpha^* + \frac{\overline{\alpha}(1-\overline{\alpha})}{\pi_1 - \lambda} * \mathrm{d}\lambda - \frac{\overline{\alpha}(1-\overline{\alpha})\lambda}{(\pi_1 - \lambda)\pi_1} * \mathrm{d}\pi_1 \tag{19}$$

and putting on the left hand side $\mathrm{d}\alpha^*$,

$$\mathrm{d}\alpha^* = \frac{\alpha^*(1-\alpha^*)}{\overline{\alpha}(1-\overline{\alpha})} * \mathrm{d}\overline{\alpha} - \frac{\alpha^*(1-\alpha^*)\lambda}{\pi_1 - \lambda} * \frac{\mathrm{d}\lambda}{\lambda} + \frac{\alpha^*(1-\alpha^*)\lambda}{\pi_1 - \lambda} * \frac{\mathrm{d}\pi_1}{\pi_1} \tag{20}$$

The relation to be estimated is of the type:

$$\mathrm{d}\alpha^* = \beta_{L1_i,L2_i}\frac{\mathrm{d}\omega}{\omega} + \beta_{L1_i,K_i}\frac{\mathrm{d}K_i}{K_i} + \beta_{L1_i,T_i}\frac{\mathrm{d}T_i}{T_i} + \beta_{L1_i,Y_i}\frac{\mathrm{d}T_i}{T_i} \tag{21}$$

The dependent variable, $\mathrm{d}\alpha^*$, is not known, but it is possible to substitute in terms of observable variables using (20). The estimated coefficient for the relative wage would be given by:

$$\overline{\beta_{L1_i,L2_i}} = \frac{\overline{\alpha}(1-\overline{\alpha})}{\alpha^*(1-\alpha^*)} * \beta^*_{L1_i,L2_i} \tag{22}$$

The elasticity equals then:

$$\sigma_{L1_i,L2_i} = 1 - \frac{\beta^*_{L1_i,L2_i}}{\alpha^*(1-\alpha^*)} = 1 - \frac{\overline{\beta_{L1_i,L2_i}}}{\overline{\alpha}(1-\overline{\alpha})} \tag{23}$$

Since $\overline{\beta_{L1_i,L2_i}} > \beta^*_{L1_i,L2_i}$, the negative term of the elasticity is overestimated, which helps to explain the negative values obtained for $\sigma_{L1_i,L2_i}$. To summarize, by not taking into account the fact that there are skilled workers in blue collar positions, the coefficient accompanying relative wages is exaggerated, leading to a negative elasticity.

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