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Gender wage gap and education: a stochastic frontier approach

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GENDER WAGE GAP AND EDUCATION: A STOCHASTIC FRONTIER APPROACH

ABSTRACT:

Purpose (limit 100 words)

The purpose of this article is to get deeper insight into the measurement of gender wage gap. A proper method to identify which part of gender wage differences are due to discrimination against women is provided, and the relationship between wage differences and education is studied.

Design/methodology/approach (limit 100 words)

The stochastic frontier approach is employed to measure wage discrimination against women using Spanish data from the European Union Statistics on Income and Living Conditions (EU-SILC). Said technique allows us to split the gender wage gap of workers displaying the same characteristics into two components: The first measures inefficiency in the job search process caused by imperfect information or gender differences concerning preferences regarding working conditions, whilst the second takes account of discrimination.

Findings (limit 100 words)

A significant level of discrimination is found in the Spanish labour market in all educational levels, but this problem is quantitatively more important when low educated workers are studied, and gender discrimination is lower for highly educated women.

Originality/value (limit 100 words)

In this paper, workers' potential wage is estimated, and gender discrimination is measured by the gender potential wage gap, since it is not depending on other wage determinants such as diverse preferences, unmeasured working abilities or imperfect information.

Keywords:

Gender pay gap, Job search, Stochastic frontier, Returns to education

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1. *Introduction*

Gender wage gap is a frequently studied problem in labour economics. Based on the human capital theory (Gary Becker, 1964), it is thought that wage differentials observed among workers could be explained because of differences in productivity. Yet, men and women with equal education and tenure, and occupying similar job posts are sometimes paid different wage rates. From an empirical point of view, in non-perfectly competitive job markets, and with imperfect information, other circumstances may affect wage rates and indeed, lead to differences between male and female worker pay. As a result, empirical analysis tends to include other control variables which reflect conditions of supply and demand.

One method often used to approach the problem of gender pay gap is the well-known Oaxaca-Blinder (1973) decomposition, in which the gender pay gap is split into two terms: differences between men and women in characteristics and differences in the reward the market allocates to them. This second component is usually associated to gender wage discrimination. To separate these two components, two different estimations are carried out, one for men and another for women. It is usually assumed that men have the non-discriminatory retribution structure. Hence, their estimated parameters are employed to compute women's counterfactual wage, that is, the wage women could be paid if their human capital endowments were rewarded in the same way as men. This kind of analysis initially focused on the mean gender wage gap, although in recent years, more elaborate studies using quantile regression techniques have analysed how this gap varies across wage distribution. See for example Albrecht, Bjorklund and Vroman (2003), or de la Rica, Dolado and Llorens (2008) in Spain.

However, the part of gender pay gap not accounted for by differences in characteristics cannot entirely be assumed to be a measure of wage discrimination, since it might be due to unobserved differences between men and women in human capital, work effort, knowledge of the job market or preferences.

In this regard, there is a growing stream of literature suggesting that most women might prefer lower paid occupations, which might lead to a segregation problem. For instance, Croson and Gneezy (2009) reported that women could be more risk averse and prefer stable jobs, and Niederle and Vesterlund (2007) proposed that women are interested in less competitive jobs. In both cases, those kinds of job are less well paid.

Our approach to the gender wage gap problem differs slightly. We base our analysis on the framework of the Job Search Theory. In this context, the actual salary that workers earn is a result of a job search process, in which individuals participating in the job market are seeking the best salary they might attain. We call it the potential wage, with workers being aware that it depends on their own human capital capacities as well as certain aspects determined by the demand side of the market.

Workers determine their reservation wage, which could be lower than their potential wage, due to imperfect information about the job market, costs associated to the job search process, and their own preferences concerning what kind of job they are seeking. Individuals tend to reject any wage offer below their reservation wage, and then continue to search for a better salary option. They will, however, accept any job offer with a pay above their reservation wage,[1] even if it is lower than their potential wage.

The potential wage can be estimated with the Stochastic Frontier Methodology. This technique was first developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broech (1977), and it was initially employed to study the technical efficiency of firms in different

[1]See McCall (1970) or Mortensen (1970) to obtain more details related to the Job Search Theory.

industries, although other applications (in health economics, education economics, economic growth, labour economics and the like) rapidly emerged.

In the labour market field, this technique is used to explain a worker's actual earnings as a result of two components: on the one hand, the potential wage, obtained as an upper frontier to data, that is, the maximum wage which a worker exhibiting the same characteristics has actually achieved, and on the other, whether the worker's actual wage is below this maximum level. The gap between the actual and estimated frontier wage is a residual term which is usually assumed as inefficiency in the job search process. In this regard, Polacheck and Robst (1988) among others found a consistence between the inefficiency scores obtained from the frontier estimation wage procedure and direct measures of the knowledge of the job market exhibited by the studied individuals.

Hofler and Polacheck (1985) used this method for the first time to study the existence of imperfect information and measured its effect on workers' actual wages. Hofler and Murphy (1992) also employed this technique to talk about "underpayment" in the job market. Since then, a growing body of literature has emerged applying this approach to exploring different problems related to the job search. In this regard, the aspect which seems to have attracted most interest is the pay gap caused by differences in race, gender or country of origin. Some pioneering papers include Robinson and Wunnava (1989), Hunt-McCool and Warren (1993) or Lang (2000). In the Spanish labour market, Díaz and Sánchez (2011).

The problem with the inefficiency term is that taking into account that it is a residual term, it can assemble various reasons why a worker does not achieve the potential wage: imperfect knowledge of the job market, discrimination, less work effort, lower unobserved skills, different preferences…

Therefore, only those workers with the best unobserved skills, with preferences oriented to achieve the highest wage rather than other characteristics of the job, more committed to work effort, and with the best job market knowledge achieve the potential wage. Ideally, there should be

no difference between male and female potential wage (given the same human capital characteristics). If so, said difference will be accounted for a gender dummy variable in the specification of the frontier, and said variable would be measuring wage discrimination against women.

In our paper, we use the method describe below to isolate gender wage discrimination. Moreover, we gain deeper insights into the role played by education and its link to gender discrimination in the job market and inefficiency in the job search process. This subject has been the focus of much recent literature addressing gender wage gap and quantile regressions. However, the current paper seeks to shed light on the relationship between education and gender pay gap from a fresh perspective[2]. The rest of the paper is organized as follows: in section 2, the methodology of stochastic frontiers and its application to the analysis of the gender pay gap is explained, and some information about the data employed is provided. Section 3 is dedicated to providing a detailed explanation of the analysis carried out and the results obtained. Finally, Section 4 summarizes the principal conclusions.

2. ***Methodology and data***

We model a semi-logarithmic earning equation, as proposed by Mincer (1974), but in which the logarithm of *i*-worker's actual wage (W_i) is explained as a result of the following expression:

$$\ln W_i = \alpha + \beta' X_i + v_i - u_i \quad (1)$$

where the maximum wage that worker can attain, that is, his/her potential or theoretical wage (w_i^p), is determined by β, a set of parameters to be estimated, X, a set of human capital and other personal characteristic variables, and v_i, a random disturbance assumed to be distributed as a normal $N(0, \sigma_v^2)$, and which confers a stochastic character to the frontier:

[2]The Spanish labour market has been the subject of scant previous research using said method. Examples in the field of gender wage gap analysis include García-Prieto et al. (2001) or Díaz and Sánchez (2011).

$$\ln W_i^p = \alpha + \beta' X_i + v_i \quad (2)$$

The actual wage is equal to or lower than the potential wage. Thus:

$$\ln W_i = \ln W_i^p - u_i \quad (3)$$

$u_i \geq 0$ being a non-negative random variable usually named inefficiency-term, and assumed to be distributed as a truncation at zero[3] of the normal distribution $N(\mu, \sigma_u^2)$ and unrelated to the independent variables *X*.

The parameters of model (1) are estimated by the method of maximum likelihood, which also provides an estimated value for the composed error term $\varepsilon_i = v_i - u_i$.

From (3), an individual's efficiency is defined by the expression:

$$\mathrm{EF}_i = \exp(-u_i) = \frac{W_i}{W_i^p} = \frac{\exp(\alpha + \beta' X_i + v_i - u_i)}{\exp(\alpha + \beta' X_i + v_i)} \quad (4)$$

The above expression will take a value of 1 if the worker has attained his/her potential wage or will be lower than 1 otherwise. Consequently, the inefficiency of that worker, which measures the gap between the worker's actual and potential wage, would be:

$$\mathrm{INEF}_i = 1 - EF_i = 1 - \exp(-u_i) \quad (5)$$

After estimation, the prediction of the efficiency will be based on its conditional expectation, $E(\exp(-u_i)|\varepsilon_i = e_i)$. From the estimation, we also obtain the variance of the composed error term $\sigma^2 = \sigma_u^2 + \sigma_v^2$, and the parameter $\gamma = \sigma_u^2/\sigma^2$, which measures the proportion of the total variability of the error term due to inefficiency.

[3] A more restrictive half-normal distribution can be tested after estimation.

$$\mathrm{CD} = \mathrm{E}\left(\frac{W_i^p{}_{/Female=0} - W_i^p{}_{/Female=1}}{W_i^p{}_{/Female=0}}\right) = 1 - e^{\hat{\beta}_{female}} \cong \hat{\beta}_{female}$$

CD is the gender wage discrimination coefficient, which is measured as male-female potential wage ratio, for simplicity, it can be proxied by $\hat{\beta}_{female}$.

The study was carried out with a set of 7,292 individuals from the 2011 Spanish wave of the European Union Statistics on Income and Living Conditions (EU-SILC). This survey provides a wide range of details concerning the labour market and workers' personal characteristics. Only employees between 25 and 65 years old and who are working more than 15 hours a week were selected. In order to calculate the hourly wage, we used the answers provided by respondents when queried about the earnings obtained the previous month in their principal job, divided by the weekly number of hours worked and the standard number of weeks per month.

As explanatory variables, we include a set of objective human capital worker characteristics, as well as certain other variables which might determine how much effort workers put into their job or which might influence employer perception concerning expected worker skills or possible commitment to the job, such that pay may be determined. Education, experience (proxied by age) and tenure are classical human capital variables included in the analysis. Occupation is a controversial variable since women might suffer discrimination by being relegated to the less well-paid categories. However, conscious of this fact, said variable is usually considered and is needed as a control when drawing comparisons among individuals' remunerations. The type of contract the worker has and whether or not they engage in any supervision in the firm or are studying whilst working are other aspects that have also been taken into account. Other control variables address the demand side of the market, such as the size of the company or the size of the town where the worker lives. Finally, certain personal circumstances have been included in the estimation such as, gender, marital and health status, whether the worker has some dependent persons in their charge or not, whether they were born in Spain or not, and whether they suffer from a chronic disease.

Table 1 summarises the most important statistical descriptive details of all these variables in the sample.

(Insert Table 1)

As can be seen, our sample consists of 7,292 observations of which 53.6% are men compared to 46.4% women. Female workers earn 10.70 Euros per hour on average, which is 1.25 Euros less than their male colleagues (11.95 Euros), such that there is a mean gender gap of 10.5%. Although males are far more experienced than females (4.1 years), they are a little older and less educated, as will be seen. In addition, 84.6% of the men have a permanent contract compared to 79.8% of the women.

As for education, the least educated workers (no education or only primary education) are the smallest group in both men and women, although the percentage is lower in the case of women; 9% compared to 14.4% of men. Moreover, female workers are more highly qualified, with 48.8% of them having attained a tertiary education degree compared to 36.5% of men.

As said before, gender wage discrimination is estimated by including a gender binary variable in the frontier (the value of which is 1 for women). If, as a result of the estimation process, a significant and negative value of its associated parameter is obtained, this will account for a not justified gender pay gap.

3. *Estimation results and efficiency study*

The initial estimation results are provided in Table 2 (Model 1). Tenure exhibits a positive influence on the logarithm of the hourly wage, although this influence is higher in the early stages of the individual's working life, its importance then decreasing, as shown by the significant negative sign of the estimated parameter accompanying the squared tenure. By contrast, Age, as a measure of overall experience in the labour market, has little significance.

Investment in education provides a growing return to individuals. Although achieving primary education does not seem to be relevant compared to having no education (the omitted category), the rest of education investment shows the classical pattern: the higher the level achieved, the higher the maximum attainable return[4]. Completing the first stage of secondary education can improve the potential wage by 7%, while finishing the second stage will raise the maximum attainable wage by 15%. Finally, a tertiary qualification could allow workers to earn a 26% higher wage[5].

(Insert Table 2)

As regards occupation, (the omitted category is Craft and Trade Workers, ISCO7), Managers (ISCO1) and Professionals (ISCO2) have the best chance of earning a high salary, while Workers in Services and Sales (ISCO5), Skilled Workers in Agriculture, Forestry and Fishery (ISCO6) together with Elementary Occupations (ISCO9) represent the worst option.

Results show that workers with a permanent contract and those who do supervision tasks in the firm can achieve a better wage, which is even higher if they work for a large company and live in a highly populated nucleus, both circumstances providing them with improved salary opportunities. Those enjoying the highest salaries live with a partner and have to take care of one or more dependent persons. In contrast, workers who access their job from a situation of unemployment face a worse potential wage, as do people who come from a large family[6], although this result may hide a reverse causal effect.

Finally, worth highlighting is the negative sign obtained for the last three variables in the table, indicating that being a woman or an immigrant, or suffering from a chronic disease is

[4] See for instance García-Prieto et al (2005) and Díaz and Sánchez (2011).
[5] For reasons of simplicity and convenience, estimated parameters are used to proxy the true elasticities.
[6] The dimension of the family, u-cons, provides a measure of the consumption needs of the family, taking into account the OECD equivalence scale.

considered a negative sign by the market, with such people facing worse wage rate opportunities for their work (9% less for immigrants and 2% for people with a chronic disease).

With regard to gender differences, the best job offers women can access are rewarded on average with 11% less pay than their male counterparts. Thus, the existence of a female glass ceiling can be considered, indicating that women cannot access the best salary options, which are given to their male colleagues who have the same human capital characteristics.

In order to decide whether, on the one hand, we can assume the existence of inefficiency in the model and, on the other, whether inefficiency effects have a simpler distribution, various generalized likelihood-ratio tests were carried out and the results are shown in Table. 3. The null hypothesis that there is no inefficiency in the model would lead us to accept that a least squared regression would be an efficient estimation procedure and, in that case, the variance parameter γ and the mean of the truncated normal distribution μ, would be equal to zero. The statistic λ=-2[log(likelihood(H_0))-log(likelihood(H_1))] is approximately distributed as a mix chi-square distribution with degrees of freedom equal to the number of parameters assumed to be equal to zero in the null hypothesis. Critical values may be found in Kodde and Palm (1986). The null hypothesis that the inefficiency effects follow the half-normal distribution would lead the mean of the truncated normal distribution μ to be equal to zero. In this case, the statistic λ is approximately distributed according to a chi-square distribution. Both hypotheses were strongly rejected.

(Insert Table 3)

Mean wage efficiency in the job search process, expressed as a percentage of the potential wage, is 88%, and no appreciable differences are found between males and females (88 and 88.1 per cent respectively). Table 4 offers some summary statistics, and Table 5 shows a disaggregated description of the efficiency scores for certain socioeconomic categories of workers, although only fairly weak differences are found among those groups.

(Insert Table 4)

(Insert Table 5)

In order to study in detail the impact of individuals' level of education on their potential wage, and to ascertain whether there is any difference in how this factor works in the case of men and women, we conducted an additional estimation by including certain gender-education multiplicative dummy variables. The detailed results are provided in Table 2 (Model 2).

In this second study, most of the previous results concerning the remaining variables persist, although we did find some interesting facts for education and its link to gender. Firstly, the return to education is higher for men than for women at all educational levels, although the magnitude of the gender gap differs depending on the level of qualifications. It is not significant for non-educated workers (just 1% of the workers in the sample). However, for those who have finished primary or secondary education, the gap is around 15%, while female workers with tertiary education face a slightly smaller gap of just 10% less than their male counterparts with the same educational level, although the latter value does not prove significant. Furthermore, analysing the values of the estimated parameters, male workers with the first stage of secondary education can achieve 12% higher pay than non-educated workers, although due to the gender gap, women might receive less pay. All of this leads to an interesting hypothesis: women need to invest in education in order to reduce the gap and thus be able to overcome the glass ceiling.

As the above analysis suggests, gender pay gap diminishes with education. In order to gain deeper insights into said relationship, in the third and final part of our study, we split individuals into three different groups, depending on the level of education: no education and primary, secondary education, and tertiary, and we carry out three new estimations, one with each set of data. The results are presented in Table 6.

(Insert Table 6)

Some interesting findings to emerge from analysing the estimation results reveal that the impact of a permanent contract decreases when the educational level rises and that its effect on the maximum salary is half as important to tertiary educated people as it is to non-educated. This is also true with regard to undertaking supervisory tasks in the firm.

Another interesting finding concerns those situations in which workers access a job when unemployed. This kind of situation penalises the salary those workers might achieve when they are highly educated but not when the level of education is the lowest. This might be a consequence of the human capital depreciation that highly skilled workers may suffer when not working, and which would prove to be far less important in the case of non-educated workers.

In contrast, studying while working proved to have a negative influence on the potential wage in the case of non-educated workers or those with only primary studies, although that circumstance was irrelevant for other educational groups. The same can be said with regard to cases in which individuals suffer from a chronic disease, since such a situation only has negative statistical relevance when their level of education is the lowest.

As far as gender analysis is concerned, the female variable in the frontier proves highly significant in every case, but its estimated parameter takes different values. In line with the results shown in Table 6, women face a 12% gap in the job market, compared to their male counterparts in the group of the lowest educated workers, this rising to 15% in the case of secondary education, which is the widest gender pay gap. It finally falls to 7% in the group of workers with tertiary education. These results confirm what was pointed to earlier: namely, that education has proved a useful tool for women in Spain with regard to reducing gender discrimination.

As regards efficiency measures, it was found that mean efficiency falls when educational qualifications rise. As said before, mean wage efficiency was 88% when the whole sample was considered. Nevertheless, after splitting workers into the three educational groups, a 90% mean efficiency level was obtained in the case of non-educated and primary educated workers, the figure

being 88% for people with secondary education, and slightly lower, 86%, in the case of tertiary education. It is worth highlighting, however, that inside each educational group, there is no significant difference between average efficiency levels achieved by men and women. All the details concerning efficiency scores are presented in Table 7.

(Insert table 7)

4. ***Discussion and Conclusions***

The present paper focuses on exploring the gender wage discrimination in Spain and its link to education. In order to achieve this purpose, gender pay gap is split into two components: gender wage discrimination and inefficiency, using the stochastic frontier approach. With this methodology, we estimate a wage frontier with a gender binary variable in order to test whether more highly rewarded women (depending on their human capital characteristics) are able to earn the same as their male counterparts. Nevertheless, workers with imperfect information, who prefer more security at work rather than higher pay, or those who show less unmeasured human capital characteristics, will earn less than their potential wage (estimated by the frontier), and will exhibit a non-negative inefficiency term.

Spanish data from European Union Statistics on Income and Living Conditions (EU-SILC) were used to conduct the study. When considering the whole sample, we found a significant difference between the best pay that men and women attained given their human capital and other control characteristics. The female potential wage is on average 11% lower than men's. This result can be compared to the work of Díez and Sánchez (2010). They estimated a wage frontier for various European countries and found a gender pay gap in Spain of 16%, although they considered a gender dummy variable in the explanation of the inefficiency. As it is explained before, being the inefficiency

a residual term, said percentage might be a mixture of discrimination and gender differences about the knowledge of the job market

This leads us to acknowledge the existence of gender discrimination in the job market and points to a glass ceiling for women. What is more, the return to education was higher for men than for women regardless of the level of education achieved.

When individuals were split into three groups depending on their level of education, gender discrimination was found to be a less serious problem for the most highly educated women. Education emerges as a helpful tool to fight gender discrimination in the job market, although education is not a definitive strategy and a significant gender pay gap still remains in this group.

One plausible explanation for this result might be that jobs requiring a low level of formal education often involve the need for firm-provided training, and workers who access this are more highly rewarded. Firms may be more inclined to invest in men, since they feel that women might be more likely to leave their work (mostly because of family duties), thus making it more difficult for firms to get a return on their investment. This occurs less frequently when talking about workers with a high level of formal education, since firms do not need to train their workers. We sought to prove this argument but there is insufficient information available in this survey to undertake such an analysis. Further research on this subject is needed.

Mean efficiency was found to be lower in the case of workers with tertiary education, although there were no differences between average efficiency levels attained by men and women in any educational group. This less efficient level found for the most highly educated group might be explained by the wide range of wage possibilities such workers face. They can attain highly rewarded jobs which require other informal human capital characteristics (such as knowledge of another language, team management skills, greater availability vis-à-vis working hours, etc.) yet they might also accept less well-paid jobs, which do not require their high level of education. This is known as

the problem of overeducation. In such instances, due to different preferences or compelled by circumstances, they remain some distance from their potential wage.

The problem of overeducation has repeatedly been pointed out in the literature and should provide the focus of further research. Nevertheless, this problem would affect men and women equally as there are no significant gender differences in efficiency scores.

The lower mean efficiency found in our analysis for the highest study level workers is consistent with the literature on inequalities in wage related to education. For example, Martins and Peteira (2004) conclude for sixteen western European countries that returns to schooling are not constant across the wage distribution. They explain that unobserved skills are more valued for those workers with the highest formal education, and hence, education is a source of within-education level inequalities.

Other interesting results show that people born in another country must also deal with lower wage rates, particularly in the case of workers with a medium level of education, while individuals suffering from a chronic disease are much less rewarded than others in the job market when they have the lowest education.

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APPENDIX

The variables used in this paper are defined as follows:

Lnwage_hour: this variable is the natural logarithm of hourly wage calculated as seen previously.

Age: the individual's age calculated as the difference between the year of birth and year of the survey.

Age_sqr: age squared.

Female: this dummy refers to being female.

Partner: a dichotomous variable that takes the value 1 if the individual is married and 0 otherwise.

Dependents: takes the value 1 if the person has dependent persons under their charge and 0 otherwise.

U-cons: this quantitative variable reflects homogeneous consumer units that exist in the household using the OECD equivalence scale.

Immigrant: a binary variable that shows when people were not born in Spain.

Chronic_dis: a dummy that shows whether the respondent suffers from a chronic disease.

Edu_No, Edu_Pri, Edu_Sec_1st, Edu_Sec_2nd and Edu_Tert: dummies that show whether the individual has no educational qualifications, primary, lower secondary, upper secondary or higher education qualifications, respectively. The reference category is a worker without studies.

Edu_pri_fe, Edu_sec_fe, Edu_sec2_fe and Edu_ter_fe: reflect the interaction between the corresponding levels of education and being female. Omitted variable is **Edu_No_fe**, hence the reference worker is man without studies.

Tenure: computes the number of years accumulated in present or previous jobs.

Tenure_Sqr: is the previous variable, tenure, squared.

ISCO0, ISCO1, ISCO2, ISCO3, ISCO4, ISCO5, ISCO6, ISCO8, ISCO9: binary variables that equal one if the survey respondent works in the armed forces (ISCO0), is a manager (ISCO1), a professional (ISCO2), a technician and associate professional (ISCO3), a clerical support worker (ISCO4), a service and sales worker (ISCO5), a skilled agricultural forestry and fishery worker (ISCO6), a craft and related trades worker (ISCO7), a plant and machine operator, or assembler (ISCO8), and elementary occupations (ISCO9), respectively, following the International Standard Classification of Occupations 2008 (ISCO-08). The variable ISCO7, which includes craft and related trades workers, is the omitted category.

Cont_perm: this binary variable distinguishes between permanent and temporary workers.

Supervisor: a dichotomous variable deemed to equal the unit if the worker coordinates or supervises someone.

Plant_big and Plant_med: dummies that reflect when the respondent works for a large company, employing over 50 staff, or a medium-size company with between 10 and 50 employees, respectively.

Pop_high and Pop_med: these binary variables equal 1 when the area where the individuals live has a high or medium level of urbanization, respectively.

Unemployment: this variable takes the value 1 when the worker was unemployed before gaining their current job and 0 otherwise.

Studying: a dummy showing whether the respondent is studying at the time of completing the survey.

TABLES

Table 1 Descriptive statistics

	Male		Female	
	Mean	SD	Mean	SD
N obs.	3905		3387	
Continuous V				
Whour	11.95	5.90	10.70	5.42
Age	44.00	9.81	43.20	9.44
Tenure	22.42	10.76	18.32	9.86
Discrete Variable				
Dependents	55.0%		53.9%	
Partner	75.8%		67.0%	
Immigrant	8.2%		9.0%	
Chron_dis	12.9%		13.9%	
City size				
Pop_high	51.4%		56.3%	
Pop_med	20.7%		19.4%	
Pop_low	27.9%		24.3%	
Education at				
Edu_no	1.1%		0.5%	
Edu_pri	13.3%		8.5%	
Edu_Sec_1	25.7%		17.9%	
Edu_Sec_2	23.5%		24.3%	
Edu_Terc	36.5%		48.8%	
Occupation				
ISCO0	1.4%		0.1%	
ISCO1	3.9%		1.2%	
ISCO2	15.5%		24.9%	
ISCO3	14.7%		9.3%	
ISCO4	9.8%		21.8%	
ISCO5	9.8%		22.7%	
ISCO6	2.1%		0.4%	
ISCO7	18.0%		2.1%	
ISCO8	16.0%		2.7%	
ISCO9	8.9%		14.9%	
Cont_perm	84.6%		79.8%	
Supervisor	29.6%		19.2%	
Firm size				
Plant_big	39.3%		36.8%	
Plant_med	33.8%		33.0%	
Plant_smal	26.9%		30.2%	
Unemployme	6.2%		6.4%	
Studying	3.8%		4.9%	

Table 2: Frontier regression results

	Model 1		Model 2	
	Coeffici	t-ratio	Coeffici	t-ratio
Constant	1.88***	19.47	1.83***	18.03
Age	-0.01	-1.15	-0.01	-1.13
Age2	0.00*	2.08	0.00*	2.10
Tenure	0.01***	6.93	0.01***	6.92
Tenure2	0.00***	-4.46	0.00***	-4.56
Edu_Pri	0.00	0.03	0.05	1.10
Edu_Sec_1	0.07*	1.75	0.12**	2.46
Edu_Sec_2	0.15***	3.68	0.21***	4.33
Edu_Terc	0.26***	6.41	0.29***	5.90
Edu_pri_fe			-0.16*	-1.78
Edu_sec_fe			-0.15*	-1.67
Edu_sec2_f			-0.17*	-1.94
Edu_ter_fe			-0.10	-1.11
ISCO0	0.16***	3.79	0.16***	3.79
ISCO1	0.39***	14.92	0.39***	14.66
ISCO2	0.40***	24.75	0.40***	24.10
ISCO3	0.15***	9.71	0.15***	9.67
ISCO4	0.08***	5.16	0.09***	5.37
ISCO5	-0.08***	-5.53	-0.08***	-4.91
ISCO6	-0.13***	-4.02	-0.13***	-3.97
ISCO8	0.01	0.87	0.01	0.66
ISCO9	-0.12***	-7.25	-0.11***	-6.65
Cont_perm	0.11***	9.91	0.11***	9.90
Supervisor	0.09***	11.00	0.10***	10.72
Plant_big	0.17***	19.42	0.17***	18.28
Plant_med	0.08***	8.62	0.08***	8.21
Pop_high	0.04***	4.24	0.04***	4.32
Pop_med	0.01	0.51	0.01	0.65
Unemploym	-0.07***	-4.26	-0.07***	-4.36
Studying	0.02	1.21	0.02	1.10
Dependents	0.06***	6.52	0.06***	6.31
Partner	0.04***	3.93	0.04***	3.77
U-cons	-0.03***	-3.89	-0.03***	-3.78
Immigrant	-0.09***	-6.42	-0.08***	-6.36
Chro_dis	-0.02*	-1.66	-0.02*	-1.67
Female	-0.11***	-13.35	0.02	0.22
	-9.41***	-4.39	-9.50***	-4.22
	1.39***	4.75	1.41***	4.51
	0.95***	77.78	0.95***	77.62
Number of	7292		7292	
Log likelih	-1733.1		-1722.6	

***, ** and * mean statistical significance at the 1%, the 5% and the 10% level respectively
Dependent variable is the natural logarithm of the hourly wage.

Table 3: Generalized likelihood-ratio tests of hypotheses of the inefficiency model's parameter

Null hypothe	Log-likelihood	Test sta (»)	Critical va
H_0: = = 0	-1764.26	62.18	8.27
H_0: = 0	-1751.94	37.54	6.63

All values are statistically significant at the 0.01 level. When the null hypothesis concerns the variance parameter , critical values are obtained from Kodde and Palm (1986).

Table 4: Efficiencies within decile ranges for men and women

Efficienc	Men		Women	
Below 0.2	1	0.03%	0	0.00%
0.2-0.3	1	0.03%	0	0.00%
0.3-0.4	1	0.03%	1	0.03%
0.4-0.5	7	0.18%	6	0.18%
0.5-0.6	21	0.54%	8	0.24%
0.6-0.7	73	1.87%	60	1.77%
0.7-0.8	587	15.03%	518	15.29%
0.8-0.9	3206	82.10%	2789	82.34%
0.9-1	8	0.20%	5	0.15%
Total	3905	100.00	3387	100.00

Table 5: Efficiencies as percentage of potential wage by socioeconomic category

	Descriptive statistics									
	Mea	SD	Min	Max	N		Mea	SD	Min	Max	N
All	880	5.1	248	961	729	Cont_perm_	880	5.3	388	947	128
Men	880	5.3	248	961	390	Supervisor	878	5.7	319	961	180
Women	881	4.9	388	960	338	Supervisor_	881	4.9	248	960	548
Edu_no	877	5.9	639	943	59	Plant_big	881	4.9	506	959	278
Edu_pri	883	4.5	460	953	80	Plant_med	882	4.6	388	953	243
Edu_Sec_1	882	4.6	450	956	160	Plant_small	878	5.8	248	961	207
Edu_Sec_2	882	4.5	506	954	173	Pob_high	881	5.0	388	961	391
Edu_Tert	878	5.7	248	961	307	Pob_med	881	5.0	388	961	391
ISCO0	887	3.1	782	938	59	Pob_low	879	5.7	248	959	191
ISCO1	874	6.4	540	961	19	Unemployme	881	5.4	388	943	46
ISCO2	876	6.3	319	959	144	Unemploy_n	880	5.1	248	961	683
ISCO3	880	5.0	532	960	88	Studying	877	5.8	524	947	31
ISCO4	881	4.4	609	956	112	Studying_nc	881	5.1	248	961	697
ISCO5	883	4.5	450	949	115	Partner	881	5.0	248	961	522
ISCO6	879	6.4	524	943	93	Partner_not	880	5.3	319	960	206
ISCO7	883	4.0	621	956	77	Immigrant	882	4.4	592	961	62
ISCO8	881	4.9	527	952	71	Immigrant_r	880	5.2	248	959	666
ISCO9	882	5.1	248	945	85	Chro_dis	880	5.3	450	952	97
Cont_perm	880	5.1	248	961	600	Chro_dis_nc	881	5.1	248	961	631

Table 6: Frontier results by education level

	No education ar		Secondary educ		Tertiary educ	
	Coeffic	t-ratio	Coeffic	t-ratio	Coeffic	t-ratio
Constant	2.14***	9.05	2.07***	17.78	1.86***	11.12
Age	-0.01	-0.83	-0.01	-1.22	0.01	0.96
Age2	0.00	0.79	0.00	1.56	0.00	0.05
Tenure	0.00	1.09	0.01***	2.94	0.01***	2.94
Tenure2	0.00	-0.14	0.00	-1.04	0.00*	-1.71
Edu_Sec_2			0.09***	7.90		
ISCO0	-0.06	-0.23	0.10***	2.22	0.26***	3.06
ISCO1	0.35***	2.67	0.27***	6.30	0.41***	9.80
ISCO2	0.01	0.03	0.25***	4.79	0.37***	11.85
ISCO3	0.10*	1.82	0.16***	7.84	0.14***	4.34
ISCO4	0.10	1.64	0.11***	5.70	0.05	1.49
ISCO5	-0.10***	-2.94	-0.05***	-2.84	-0.13***	-3.44
ISCO6	-0.14***	-2.45	-0.13***	-3.32	-0.13	-0.98
ISCO8	-0.01	-0.28	0.03	1.36	0.01	0.20
ISCO9	-0.13***	-4.35	-0.0***	-3.62	-0.19***	-3.88
Cont_perm	0.15***	5.20	0.11***	7.65	0.08***	4.37
Supervisor	0.13***	4.10	0.12***	8.72	0.08***	6.04
Plant_big	0.16***	6.27	0.18***	13.92	0.16***	10.19
Plant_med	0.07***	3.05	0.07***	5.74	0.09***	5.14
Pop_high	0.06***	2.69	0.04***	3.19	0.03**	2.21
Pop_med	0.00	-0.10	0.01	0.74	0.01	0.52
Unemploym	-0.01	-0.39	-0.07***	-3.08	-0.12***	-3.80
Studying	-0.24**	-2.45	0.05	1.56	0.02	1.03
Dependent	0.05	1.88	0.04***	2.82	0.08***	4.69
Partner	0.03	1.02	0.05***	3.49	0.03**	2.08
U-cons	-0.02	-0.95	-0.03***	-2.97	-0.03***	-2.68
Immigrant	-0.06*	-1.82	-0.11***	-6.02	-0.09***	-3.45
Chro_dis	-0.09***	-3.38	-0.01	-0.86	0.00	-0.19
Female	-0.12***	-4.75	-0.15***	-12.59	-0.07***	-5.57
	-7.41*	-1.67	-8.75	-0.96	-10.93***	-3.76
	0.88*	1.95	1.20	0.99	1.85***	4.07
	0.92***	217.5	0.94***	161.2	0.96***	809.6
Number of	866		3348		3078	
Log likelih	-13.765		-563.87		-91.692	

***, ** and * mean statistical significance at the 1%, the 5% and the 10% level respectively. Dependent variable is the natural logarithm of the hourly wage.

Table 7: Efficiencies as a percentage of potential wage by gender and educationa

Descriptive statistics					
	mean	SD	Min	Max	N
No education and primary education					
All	90.3	3.6	54.3	95.8	86
Men	90.3	3.7	54.6	95.8	56
Women	90.4	3.6	54.3	95.5	30
Secondary education					
All	88.8	4.6	46.0	96.0	334
Men	88.7	4.8	52.0	96.0	191
Women	88.8	4.4	46.0	95.0	142
Tertiary education					
All	86.3	6.1	23.2	95.5	307
Men	86.2	6.5	23.2	95.5	142
Women	86.4	5.8	35.7	95.4	165