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Gender pay gap and income inequality

Measurement of gender inequalities in the French labour market using efficiency measures

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Abstract

Discrimination against females occurs at different stages of their career path. The wage gap is apparent at the top (glass ceiling) as well as at the bottom (sticky floor) of wage distribution. Using labour survey data from France, this paper investigates the existence of gender pay gaps that reflect the notions of "glass ceiling" and "sticky floor" using the Data Envelopment Analysis (DEA) and the Malmquist Index (MI) measured in output and input. Furthermore, a complete measure of the gender pay gap is proposed with a pseudo Hicks-Moorsteen Index (HMI). The analysis is replicated to different economic activities and occupations. The results reveal the existence of glass ceilings and sticky floors in almost all economic sectors and occupations.

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1. Introduction

1. Although substantial progress has been made towards its eradication in recent decades, gender discrimination is still present in all societies, regardless of their level of development (Weichselbaumer and Winter-Ebmer, 2005). Women are still not as favoured as men in many dimensions, including the labour market. This structural problem has emerged due to the historical social assignment of roles according to a biological condition, which has created stereotypes with lower social value for women. The stereotype of women as unpaid workers in the household and caregivers of children and the elderly limits their adequate insertion into the labour market. This is because they probably have to access part-time jobs and achieve less work experience than men.
2. Thus, the existence of wage gaps between men and women could in principle be justified because women work fewer hours or because they have less work experience than men. However, when isolating these factors, the wage gap does not disappear, even though in certain cases women present higher educational levels than men (Carrillo et al., 2014).
3. Another form in which gender discrimination manifests itself is occupational and sectoral segregation. This concentration of one sex in certain economic activities or in certain occupations has been highlighted by the International Labour Organization (ILO) (2019), showing that there is a high probability that a woman will be engaged in low paying jobs such as service and trade clerks, and elementary occupations. However, even when comparing men and women in the same position and sector, there are still differences in the salaries they receive.
4. The impossibility for women to attain high-paying occupations is a phenomenon known as the “glass ceiling”, where gender pay gaps are wider at the top of the wage distribution. The term is used to refer to the fact that men dominate the upper strata of the managerial pyramid. Qualified females look through the “glass ceiling” having in mind the potential they carry and own but are not capable to break through the invisible artificial barriers formed by attitude and organizational prejudices.
5. In contrast, the scenario where females at the bottom of wage distribution, i.e., at the beginning of their careers, are at a greater disadvantage is known as the “sticky floor”. Specifically, women are stuck at the bottom of a career with very limited possibilities of upward or sideway movements (Hejase and Dah, 2014). Although women who run into glass ceilings are more educated and privileged than those who experience the sticky floor, women in both situations have some similarities. Both have low mobility and find themselves unable to better their situation.
6. There is a large empirical literature on the gender pay gap using unadjusted and adjusted methods of measurement. An unadjusted pay gap measure provides ‘raw figures’ on the average differences in pay, whereas an adjusted pay gap measures the pay gap after adjusting for various factors such as type of occupation, education and experience that might influence the earnings differentials.
7. The most common adjusted methodology is the Blinder-Oaxaca decomposition (1973) and its variations, which explain the difference in the means of the salary between male and female by the estimation of a wage or earnings equation by gender, separately, assuming that males have a non-discriminatory wage structure. Then, the wage gap is decomposed in explained differences due to differences in productivity and unexplained differences attributed to gender discrimination.

8. Many authors have looked at these differences in developed (Arulampalam et al., 2007; Albrecht et al., 2009; Nicodemo, 2009) and developing regions (Ñopo et al., 2009; Badel and Peña, 2008; Bórraz and Robano, 2010; García and Winter, 2006). These studies assess what happens to the gender wage gap at different points of the wage distribution, although some of them just analyse the mean difference. Albrecht et al. (2009), Badel and Peña (2008), and Perticará and Astudillo (2009) found that the wage gap at the top of the distribution is notably larger than in the middle (glass ceiling). Arulampalam et al. (2007), Borráz and Robano (2010), and Nicodemo (2009) showed evidence that for some countries the gender wage gap can be larger at the bottom of the wage distribution (sticky floors).
9. Relatively few studies have been carried out on gender pay gap using an adjusted method, specifically, parametric and non-parametric efficiency approaches. The efficiency approach is a methodology usually applied to analyse inefficiency in firms' production where a production frontier shows the maximum amount of output attainable with a given level of inputs (Hofler and Polacheck, 1985).
10. The efficiency frontier methodology can contribute to a better estimation of the wage gap and discrimination because it establishes a relationship between the maximum wage attainable by an individual, given their human capital and other personal characteristics, instead of considering an average wage obtained by the estimation of a reduced wage equation. Then, the earnings function represents the relation between the human capital variables (inputs) and the maximum wage attainable (output) and allows to compare the wage obtained by a worker with their potential and theoretical wage.
11. Robinson and Wunnava's (1989) paper is one of the first attempts to measure discrimination using the frontier methodology. The authors used the parametric method, stochastic frontiers, and found out that, if the worker earns less than its potential wage, that represents inefficiency in the transformation of human capital variables (schooling, experience, and tenure) into earnings. Other studies (Fall et al., 2021; García and Gómez, 2017; Díaz and Sánchez, 2011; Bishop et al., 2007) using the same method, show that a significant part of the gender wage gap in all the countries analysed is not attributable to differences in human capital endowment or personal and job-related characteristics.
12. Another alternative approach to assess efficiency is the non-parametric method, Data Envelopment Analysis (DEA) (Charnes, Cooper, and Rhodes, 1978). As in the stochastic frontiers, we assume that human capital characteristics are rewarded the same way for male and female, so each group reaches the same level of efficiency in the economy. Any differences in the revealed efficiency we can call discrimination.
13. Mohan and Ruggiero (2007) and Bowlin and Renner (2008) use DEA to estimate differences in pay between male and female workers. Additionally, Amado et al. (2018) developed an enhanced method to measure and decompose the gender pay gap, based on DEA and the Malmquist Index (MI) under CRS assumption. The authors used (1) the DEA to estimate a pay frontier representing the maximum pay that could be achieved for certain characteristics and (2) measured the gender pay gap with a MI that compared male and female pay data. Findings suggest a substantial pay gap in the 20 European countries that were included in the study. In particular, when controlling for level of education and tenure, females received 19.51 percent lower pay than males. They also found that in some countries, the realized wages of female workers are farther from their optimal pay frontiers than those of male workers, and this distance results in a larger pay gap. However, in other countries, female workers' realized wages are closer to the pay frontier than males, resulting in a smaller pay gap.

14. The major advantage of DEA over other methods that determine efficiency, such as regressions or stochastic frontiers, is that the relative weights of the variables do not need to be known, a priori. (Wagner & Shimshak, 2007). It is based on a distance function approach and hence can handle multiple outputs and multiple inputs; it does not assume any specific behavioural assumptions of the firm or individual (e.g., cost minimization or profit maximization); it makes no assumption regarding the distribution of efficiencies; and it requires no a priori information regarding the values of either the inputs or the outputs (Johnes & Yu, 2008). Thus, this efficiency approach seems particularly adapted to analyse the gender wage gap.

15. Even though the three studies presented above have already used DEA to analyse differences in wages between male and female workers, the method we propose differs from the one used in these studies because we measure the MI both in input and in output and reinterpret them. Indeed on the one hand, the MI in input is interpret as a measure of the "glass ceiling" effect and, on the other hand, the MI in output is consider as a measure of the "sticky floor" effect. Then, the calculation of the ratio of these two MI would be a complete measure of the gender pay gap and can be viewed as a pseudo Hicks-Moorsteen Index (HMI).

16. To capture thus the effects of occupational and economic activity segregation on the gender pay gap, we propose to replicate our analysis to different economic activities or sectors and occupations. The comparison of the results will allow us to identify the labour market segment where gender pay gap and especially "glass ceilings" and "sticky floors" are the most important.

17. The above-described approach is applied to a sample of 40.978 French male and female workers. We use data from the nationally representative Employment Survey in France conducted in 2019, before COVID-19. France provides an interesting case for a detailed study of gender occupational inequalities.

18. According to the ILO (2019), women continue to face significant barriers to entering the labour market and advancing in their careers. Barriers to participation, persistent occupational and sectoral segregation, and a disproportionate share of unpaid housework and caregiving prevent them from gaining equal access to opportunities. For illustration, women remain underrepresented in the labour market: 63% of women are currently employed, compared to 69.3% of men. In other words, there is a gender employment gap of 6.3%. On the other hand, the gender pay gap in France is 12.7% in favour of men, which varies according to the worker's occupation or position. If we consider the gender pay gap for management and professional positions, it is 14% in favour of men.

2. Methodology

19. The method proposed is based on Data Envelopment Analysis (DEA) (Charnes, Cooper, & Rhodes, 1978) and the Malmquist Index (MI) (Camanho & Dyson, 2006; Caves, Christensen, & Diewert, 1982; Malmquist, 1953).

2.1. DEA models

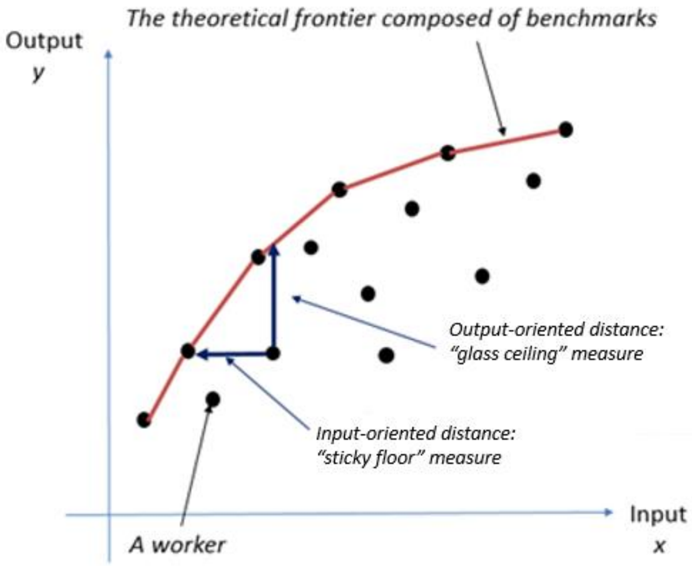
20. Introduced by Charnes, Cooper and Rhodes in 1978, the DEA models are non-parametric methods to measure a decision-making units (DMU)'s efficiency thanks to a sample of homogeneous DMUs. A DMU can be any kind of organization (company, university, hospital, etc) or an individual as a worker for example. A DMU has resources (inputs) to

achieve performance objectives (outputs). For example, a worker can accumulate human capital (inputs) to earn salary (outputs).

21. The principle of the method is to define, in a first step, a theoretical production frontier. This frontier represents the set of what is technically possible to produce for each combination of inputs. When applying a DEA model under variables returns to scale (VRS)[1], the frontier is composed of the DMUs with the highest combination of inputs and outputs. This means that there is no other DMU that can have higher outputs with equivalent or less inputs or that can use less inputs for equivalent or superior outputs. For example, for a sample of workers, the theoretical frontier will represent the highest potential salary for a given level of human capital. These are considered the benchmarks.
22. In a second step, we measure the distance between the position of the DMUs and this theoretical frontier. This distance represents the efficiency score of the DMUs. Closer a DMU is to the frontier, higher is its efficiency.
23. However, under VRS assumption, there are mainly two ways to measure the distance to the frontier: input-oriented distance and output-oriented distance. In input-oriented models, for a given level of outputs, the DMU minimizes the inputs used. For example, for a given salary, a worker tries to minimize the duration of human capital accumulation. In output-oriented models, for a given level of inputs, the DMU maximizes the amount of outputs produced. For example, for a given level of human capital a worker tries to maximize its salary. Figure 1 illustrates the method in the simple case of one input and one output.
24. Consequently, in the case of workers using human capital characteristics as inputs to obtain salary as outputs, we propose to interpret output-oriented efficiency score as a measure of inequalities in the evolution of remuneration. Consequently, that corresponds to the large definition of the “glass ceiling”, when individuals are blocked for the evolution of their wage. On the other hand, efficiency scores measured in input can be interpreted as a measure of inequalities in the career paths. Indeed, it represents the fact that some individuals have spent more years of human capital (seniority or education) than others for a given wage. Thus, it can be interpreted as a measure of the “sticky floor”.
25. Mathematically, the efficiency scores are computed thanks to linear programming. The method computes the ratio of multiple outputs over multiple inputs which measures the efficiency of DMUs and evaluates their relative efficiency.

[1] Returns to scale is a concept that expresses the ratio of inputs to outputs. This ratio can be constant or variable, i.e., it can be increasing or decreasing. In DEA, VRS models are used to calculate efficiency scores of DMUs based on their inputs and outputs. VRS models allow for the possibility of variable returns to scale and are therefore more flexible than constant returns to scale (CRS) models, which assume a constant relationship between inputs and outputs.

Figure 1. Frontier and efficiency measures



26. A DMU uses multiples inputs $X = (x_1, \ldots, x_s)$ to produce multiples outputs $Y = (y_1, \ldots, y_m)$ and its efficiency score is defined by the following quotient:

$$efficiency = (u_1 y_1 + \ldots + u_m y_m)/(v_1 x_1 + \ldots + v_s x_s) = (U \cdot Y)/(V \cdot X) \quad (1)$$

27. where $V = (v_1, \ldots, v_s)$ and $U = (u_1, \ldots, u_m)$ denote the weights assigned to the inputs and outputs quantities respectively. Vectors U and V must be determined by the linear programming problems, called VRS input-oriented (2) and output-oriented (3) models in the multiplier form, which are expressed as the following:

VRS input-oriented:

$$efficiency = \underset{u,v}{Max} \sum_{i=1}^{m} u_i y_{i,j_0} + u_0 \quad (2)$$
$$s.t.$$
$$-\sum_{i=1}^{s} v_i x_{ij} + \sum_{i=1}^{m} u_i y_{ij} + u_0 \leq 0 \ \forall_j = 1, \ldots, j_0, \ldots, N$$
$$\sum_{i=1}^{s} v_i x_{ij} = 1$$
$$u_i \geq 0 \ \forall_i = 1, m$$
$$v_i \geq 0 \ \forall_i = 1, s$$

VRS output-oriented:

$$efficiency = \underset{u,v}{Min} \sum_{i=1}^{s} v_i x_{i,j_0} + v_0 \quad (3)$$
$$s.t.$$
$$-\sum_{i=1}^{m} u_i y_{ij} + \sum_{i=1}^{s} v_i x_{ij} + v_0 \geq 0 \ \forall_j = 1, \ldots, j_0, \ldots, N$$
$$\sum_{i=1}^{m} u_i y_{ij} = 1$$
$$u_i \geq 0 \ \forall_i = 1, m$$
$$v_i \geq 0 \ \forall_i = 1, s$$

2.2 DEA- Based Malmquist Productivity Index

28. The MI introduced by Caves et al. (1982) and developed further in the context of performance assessments by Fare et al. (1994), originally proposes to compare the efficiencies between periods t and $t+1$. However, for our study instead of time periods we use genders (male and female workers).

29. Our objective, by using DEA, is to calculate the potential salary for each individual using two benchmarks or frontiers. First, each individual's human capital resources (inputs), and remuneration (outputs) are evaluated relative to members of the same gender to produce a same-sex measure of wage gap, and to members of the other sex, producing an other-gender measure of wage gap. These measures are calculated input and output-oriented and allow the production of the MI to compare the efficiencies of a given DMU whether in relation to the male or female frontier.

30. Suppose a female DMU uses inputs $X^F = (x_1^F, \ldots, x_s^F)$ to produce the output $Y^F = (y_1^F, \ldots, y_m^F)$. Also suppose a male DMU uses inputs $X^M = (x_1^M, \ldots, x_s^M)$ to produce the output $Y^M = (y_1^M, \ldots, y_m^M)$.

31. Models (4) to (7) below are used to determine the MI in output as a measure of the "glass ceiling":

$$D_O^F(X_O^F, Y_O^F) = \underset{u,v}{Max} \sum_{i=1}^{m} v_i \mathrm{x}_{i,j_0}^F + v_0 \tag{4}$$

$$\begin{aligned} & s.t. \\ & -\sum_{i=1}^{s} u_i \mathrm{y}_{ij}^F + \sum_{i=1}^{m} v_i \mathrm{x}_{ij}^F + v_0 \geq 0 \ \ \forall_j = 1, \ldots, j_0, \ldots, NF \\ & \sum_{i=1}^{s} u_i \mathrm{y}_{ij}^F = 1 \\ & u_i \geq 0 \ \ \forall_i = 1, m \\ & v_i \geq 0 \ \ \forall_i = 1, s \end{aligned}$$

$$D_O^M(X_O^F, Y_O^F) = \underset{u,v}{Max} \sum_{i=1}^{m} v_i \mathrm{x}_{i,j_0}^F + v_0 \tag{5}$$

$$\begin{aligned} & s.t. \\ & -\sum_{i=1}^{s} u_i \mathrm{y}_{ij}^M + \sum_{i=1}^{m} v_i \mathrm{x}_{ij}^M + v_0 \geq 0 \ \ \forall_j = 1, \ldots, j_0, \ldots, NF \\ & \sum_{i=1}^{s} u_i y_{ij}^F = 1 \\ & u_i \geq 0 \ \ \forall_i = 1, m \\ & v_i \geq 0 \ \ \forall_i = 1, s \end{aligned}$$

$$D_O^M(X_O^M, Y_O^M) = \underset{u,v}{Max} \sum_{i=1}^{m} v_i x_{i,j_0}^M + v_0 \tag{6}$$

$$\begin{aligned} & s.t. \\ & -\sum_{i=1}^{s} u_i \mathrm{y}_{ij}^M + \sum_{i=1}^{m} v_i \mathrm{x}_{ij}^M + v_0 \geq 0 \ \ \forall_j = 1, \ldots, j_0, \ldots, N\,M \\ & \sum_{i=1}^{s} u_i \mathrm{y}_{ij}^M = 1 \\ & u_i \geq 0 \ \ \forall_i = 1, m \\ & v_i \geq 0 \ \ \forall_i = 1, s \end{aligned}$$

$$D_O^F(X_O^M, Y_O^M) = \underset{u,v}{Max} \sum_{i=1}^{m} v_i x_{i,j_0}^M + v_0 \tag{7}$$

$$\begin{aligned} & s.t. \\ & -\sum_{i=1}^{s} u_i \mathrm{y}_{ij}^F + \sum_{i=1}^{m} v_i \mathrm{x}_{ij}^F + v_0 \leq 0 \ \ \forall_j = 1, \ldots, j_0, \ldots, NM \\ & \sum_{i=1}^{s} u_i \mathrm{y}_{ij}^M = 1 \\ & u_i \geq 0 \ \ \forall_i = 1, m \\ & v_i \geq 0 \ \ \forall_i = 1, s \end{aligned}$$

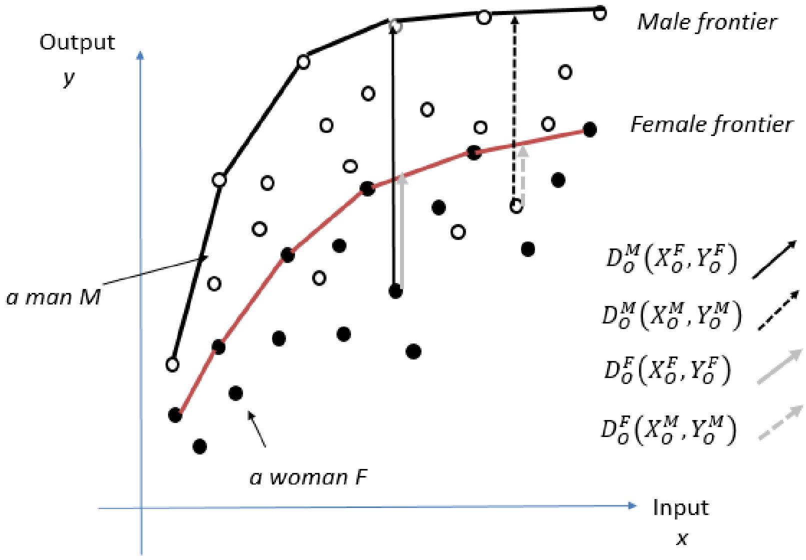
32. The output-oriented Malmquist productivity index is given as:

$$MI_O = [MI_O^M \cdot MI_O^F]^{1/2}$$

$$MI_O = \left[\frac{D_O^M(X_O^F, Y_O^F)}{D_O^M(X_O^M, Y_O^M)} \cdot \frac{D_O^F(X_O^F, Y_O^F)}{D_O^F(X_O^M, Y_O^M)}\right]^{1/2}$$

33. The above measure is the geometric mean of two Malmquist productivity indexes, MI_O^M , the output-oriented MI in reference to the male frontier, and MI_O^F in reference to the female frontier[2]. Each MI is the ratio of the output-oriented distance between a male position to the frontier and a female position to the frontier (represented in Figure 2).

Figure 2. Male and female frontiers and output-oriented distances to them



34. Consequently, it represents the output-oriented distance between female and male, i.e., a distance due to a "glass ceiling". Following Fare et al. (1992), $MI_O > 1$ ($MI_O < 1$) means the existence of a "glass ceiling" in favour of male (female). $MI_O = 1$ means no discrimination between male and female workers.

35. Models (8) to (11) below are used to determine the MI in input as a measure of the "sticky floor":

$$D_I^F(X_I^F, Y_I^F) = \underset{u,v}{Max} \sum_{i=1}^{m} u_i y_{i,j_0}^F + u_0 \quad (8)$$

$$s.t.$$

$$-\sum_{i=1}^{s} v_i x_{ij}^F + \sum_{i=1}^{m} u_i y_{ij}^F + u_0 \leq 0 \;\; \forall_j = 1, \dots, j_0, \dots, NF$$

$$\sum_{i=1}^{s} v_i x_{ij}^F = 1$$

$$u_i \geq 0 \;\; \forall_i = 1, m$$

$$v_i \geq 0 \;\; \forall_i = 1, s$$

[2] Differences between the MI in reference to the male frontier and the female frontier are due to differences in the shape of the frontier between male and female.

$$D_I^M(X_I^F, Y_I^F) = \underset{u,v}{Max} \sum_{i=1}^{m} u_i y_{i,j_0}^F + u_0 \quad (9)$$
$$s.t.$$
$$-\sum_{i=1}^{s} v_i x_{ij}^M + \sum_{i=1}^{m} u_i y_{ij}^M + u_0 \leq 0 \ \ \forall_j = 1, \dots, j_0, \dots, NF$$
$$\sum_{i=1}^{s} v_i x_{ij}^F = 1$$
$$u_i \geq 0 \ \ \forall_i = 1, m$$
$$v_i \geq 0 \ \ \forall_i = 1, s$$

$$D_I^M(X_I^M, Y_I^M) = \underset{u,v}{Max} \sum_{i=1}^{m} u_i y_{i,j_0}^M + u_0 \quad (10)$$
$$s.t.$$
$$-\sum_{i=1}^{s} v_i x_{ij}^M + \sum_{i=1}^{m} u_i y_{ij}^M + u_0 \leq 0 \ \ \forall_j = 1, \dots, j_0, \dots, NM$$
$$\sum_{i=1}^{s} v_i x_{ij}^M = 1$$
$$u_i \geq 0 \ \ \forall_i = 1, m$$
$$v_i \geq 0 \ \ \forall_i = 1, s$$

$$D_I^F(X_I^M, Y_I^M) = \underset{u,v}{Max} \sum_{i=1}^{m} u_i y_{i,j_0}^M + u_0 \quad (11)$$
$$s.t.$$
$$-\sum_{i=1}^{s} v_i x_{ij}^F + \sum_{i=1}^{m} u_i y_{ij}^F + u_0 \leq 0 \ \ \forall_j = 1, \dots, j_0, \dots, NM$$
$$\sum_{i=1}^{s} v_i x_{ij}^M = 1$$
$$u_i \geq 0 \ \ \forall_i = 1, m$$
$$v_i \geq 0 \ \ \forall_i = 1, s$$

36. The input-oriented Malmquist productivity index is given as:

$$MI_I = [MI_I^M \cdot MI_I^F]^{1/2}$$
$$MI_I = \left[\frac{D_I^M(X_I^F, Y_I^F)}{D_I^M(X_I^M, Y_I^M)} \cdot \frac{D_I^F(X_I^F, Y_I^F)}{D_I^F(X_I^M, Y_I^M)}\right]^{1/2}$$

37. Similarly, the input-oriented MI is the geometric mean of the input-oriented MIs in reference to each frontier. Each MI is the ratio of the input-oriented distance between a male position to the frontier with a female position to the frontier. Consequently, it represents the input-oriented distance between male and female, i.e., a distance due to a “sticky floor”. Conversely to the output-oriented model, $MI_I < 1$ ($MI_I > 1$) means a “sticky floor” effect in favour of male (female). $MI_I = 1$ means no discrimination between male and female workers.

2.3. The ratio of Malmquist indexes and a pseudo Hicks-Moorsteen Index (HMI)

38. We can propose a complete measure of the gender pay gap by considering both the input-oriented and the output-oriented MIs. Thus, we can compute the geometric mean of these two MIs as follows:

$$pseudo\ HMI = \left[\frac{MI_O}{MI_I}\right]^{1/2} \quad (14)$$

39. This measure reminds the Hicks-Moorsteen Index as it is a ratio of two MIs, one output-oriented and one input-oriented. Therefore, we can call it “pseudo-Hicks-Moorsteen Index”[3]. If the pseudo-HMI is larger than one, then it will show the existence of a gender pay gap.

[3] The Hicks-Moorsteen index is the ratio of two MIs, one output-oriented and one input-oriented. However, the definition of the MIs differs from the MIs that we consider in this article.

3. Data

3.1. Survey and sample

40. We use the nationally representative Labour Force Survey (LFS) data from France (Enquête Emploi) carried out in 2019, before COVID-19 outbreak. We consider a sample of working age individuals (15 years and older) employed in formal economy. As measure of human capital for the inputs we consider the number of years of education and the number of years of work seniority. The number of years of education is measured as the theoretical number of years of education of the highest diploma obtained. Our output variable is the hourly earnings in euros. After the application of the relevant filters, the removal of extreme outliers, inconsistent values and individuals, and the removal of the non-representative economic activities (less than 1% of all economic activities), the final sample of workers used to calculate the averages for each of the economic activity and occupation included a total of 40,978 workers (19,294 men and 21,684 women).

3.2. Descriptive statistics

41. Table 1 presents the summary statistics for the variables used in the analysis: (1) years of education, (2) years of work seniority, and (3) hourly earnings. From Table 1 we notice that we are dealing with a sample of middle educated workers: both male and female workers have, on average, slightly more than 12 years of education; however, women are more educated than men. In what concerns job seniority, we observe an average of 11.9 years for male and 12.6 for female. The gender pay gap is a persistent issue in France, it was around 13.4% in 2019. This means that, on average, women in France earn 86.6 cents for every euro earned by men, although women are more educated and have more years of work seniority.

Table 1. Summary statistics of the inputs and outputs (LFS, 2019)

	Male			Female		
	Mean no. of years of education	**Mean no. of years of work seniority**	**Mean hourly earnings (€)**	**Mean no. of years of education**	**Mean no. of years of work seniority**	**Mean hourly earnings (€)**
Mean	12,8	11,9	14,3	13,2	12,6	13,0
Variation	0,2	0,9	0,4	0,2	0,9	0,4
Min	5	0	2,2	5	0	2,4
Max	20	48	58,8	20	47	65,6
Unadjusted gender pay gap :		**13,4%**				

Table 2. Descriptive statistics of the variables used in the DEA model by economic activity and gender

Economic activity	Gender	No. of workers	Years of education				Years of work seniority				Mean hourly earnings (€)			
			Mean	Variation	Min	Max	Mean	Variation	Min	Max	Mean	Variation	Min	Max
Agriculture, forestry and fishing	M	313	11,8	0,1	5	17	9,3	1,2	0	43	10,7	0,3	2,7	29,5
	F	125	12,1	0,2	5	20	9,0	1,1	0	44	10,6	0,4	2,8	25,6
Manufacturing	M	3707	12,5	0,2	5	20	13,6	0,8	0	46	15,1	0,4	2,2	39,9
	F	1623	12,8	0,2	5	20	12,6	0,9	0	44	13,5	0,4	2,6	45,3
Electricity, gas, steam and air conditioning supply	M	283	13,3	0,2	9	20	15,3	0,7	0	41	18,5	0,3	4,0	39,6
	F	96	13,2	0,2	5	20	13,9	0,7	0	40	15,9	0,3	4,4	30,9
Water supply; sewerage, waste management and remediation	M	255	11,9	0,2	5	20	12,2	0,9	0	42	14,0	0,3	6,0	30,3
	F	87	13,2	0,2	5	17	10,6	0,8	0	37	12,9	0,3	7,8	27,8
Construction	M	1956	11,6	0,2	5	20	9,0	1,0	0	45	12,8	0,3	2,9	34,1
	F	313	13,2	0,2	5	20	9,2	1,0	0	37	12,6	0,3	4,6	32,0
Wholesale and retail trade; repair of motor vehicles	M	2581	12,3	0,2	5	20	9,4	1,0	0	43	12,6	0,4	2,6	36,5
	F	2691	12,6	0,2	5	20	9,8	1,0	0	44	11,6	0,4	2,7	44,3
Transportation and storage	M	1566	11,8	0,2	5	20	12,7	0,9	0	47	14,0	0,4	4,1	42,1
	F	690	12,6	0,2	5	17	15,0	0,7	0	43	13,8	0,4	3,8	65,6
Accommodation and food service activities	M	578	11,8	0,2	5	17	6,2	1,4	0	41	10,7	0,4	2,3	33,3
	F	656	12,1	0,2	5	20	7,7	1,2	0	47	10,2	0,3	2,8	39,8
Information and communication	M	862	15,0	0,1	5	20	9,6	1,1	0	44	17,5	0,3	4,4	43,8
	F	421	14,8	0,1	5	20	10,5	1,0	0	43	15,7	0,4	4,1	40,7
Financial and insurance activities	M	579	14,7	0,2	5	20	12,6	0,9	0	43	18,0	0,3	3,6	36,2
	F	1022	14,3	0,1	5	20	13,7	0,8	0	44	15,9	0,3	3,2	49,1
Real state activities	M	158	13,0	0,2	5	20	9,8	1,0	0	41	13,2	0,4	3,9	31,3
	F	252	13,1	0,2	5	17	10,0	0,9	0	38	12,6	0,3	5,1	38,0
Professional, scientific and technical activities	M	1055	14,8	0,2	5	20	9,3	1,0	0	41	16,3	0,3	3,2	39,9
	F	1144	14,6	0,2	5	20	9,7	1,0	0	45	14,8	0,3	2,4	41,8
Administrative and support service activities	M	704	12,2	0,2	5	20	7,6	1,1	0	41	12,6	0,4	3,4	38,7
	F	696	12,8	0,2	5	20	8,0	1,1	0	43	11,8	0,4	3,3	36,3
Public administration and defence; compulsory social security	M	1939	12,6	0,2	5	20	17,7	0,6	0	48	14,5	0,3	2,9	38,2
	F	2685	13,1	0,2	5	20	17,9	0,7	0	47	13,6	0,3	3,4	44,2
Education	M	1171	14,9	0,2	5	20	16,8	0,7	0	44	17,2	0,5	3,7	58,8
	F	2894	14,5	0,2	5	20	15,2	0,7	0	46	14,6	0,5	4,1	56,9
Human health and social work activities	M	1087	12,9	0,2	5	20	11,9	0,9	0	45	13,1	0,4	2,5	39,6
	F	5354	12,5	0,2	5	20	12,3	0,9	0	44	12,0	0,4	2,4	53,5
Arts, entertainment and recreation	M	244	13,2	0,2	5	17	10,6	1,0	0	43	12,9	0,4	2,9	53,1
	F	277	13,8	0,2	5	20	10,8	1,0	0	43	12,0	0,3	4,0	34,3
Other service activities	M	256	13,1	0,2	9	20	10,3	1,0	0	39	12,9	0,4	3,6	33,1
	F	658	12,9	0,2	5	20	9,2	1,0	0	42	11,5	0,4	2,5	34,1

42. Continuing with summary statistics, Table 2 presents the variables by economic activities and gender. The average hourly earnings of female workers were lower than those of male workers in all economic activities, although in most of these sectors female workers are more educated, especially in construction, transportation and storage, public administration and arts, entertainment and recreation.

43. These differences in earnings in favour of men represent the unadjusted gender pay gap, which, for each economic activity, is positive. It varies from 0.9% (Agriculture, forestry and fishing) to 15.3% (Education).

44. Additionally, Table 3 presents the summary statistics of the variables by occupation and gender. Women are concentrated in lower-paying occupations, such as clerical support, service work and elementary occupations, while men are more likely to be in managerial positions. The earnings of female workers are lower than those of male workers in all occupations. The unadjusted gender pay gap varies from 5.9% (Clerical support workers) to 14.5% (Skilled agricultural, forestry and fishery workers).

Table 3. Descriptive statistics of the variables used in the DEA model by occupation and gender

Occupation	Gender	No. of workers	Years of education				Years of work seniority				Mean hourly earnings (€)			
			Mean	Variation	Min	Max	Mean	Variation	Min	Max	Mean	Variation	Min	Max
Managers	M	1544	14,9	0,2	5	20	14,2	0,8	0	45	20,0	0,3	4,7	39,9
	F	1195	15,0	0,2	5	20	14,4	0,8	0	47	18,0	0,3	3,2	49,1
Professionals	M	3523	15,3	0,2	5	20	12,7	0,9	0	45	18,2	0,4	2,9	58,8
	F	4560	15,5	0,1	9	20	14,1	0,8	0	46	16,8	0,4	2,9	56,9
Technicians and associate professionals	M	4766	12,7	0,2	5	20	13,0	0,9	0	48	14,6	0,3	2,5	42,1
	F	5346	13,4	0,1	5	20	13,4	0,9	0	45	13,4	0,3	2,4	41,5
Clerical support workers	M	1010	12,4	0,2	5	17	14,0	0,8	0	47	12,5	0,3	3,4	30,5
	F	3221	12,7	0,2	5	20	13,6	0,8	0	46	11,8	0,3	2,6	41,8
Service and sales workers	M	1838	11,9	0,2	5	20	10,0	1,0	0	46	11,5	0,3	2,3	39,9
	F	4534	11,7	0,1	5	20	10,2	1,0	0	47	10,2	0,3	2,4	65,6
Skilled agricultural, forestry and fishery workers	M	470	11,4	0,1	5	17	8,1	1,2	0	43	10,3	0,3	2,7	30,1
	F	81	11,1	0,2	5	17	7,7	1,1	0	34	8,8	0,2	2,8	15,1
Craft and related trades workers	M	2880	11,3	0,1	5	17	10,4	1,0	0	45	11,9	0,3	2,2	35,1
	F	272	11,4	0,2	5	17	10,1	1,0	0	43	10,6	0,3	2,6	31,4
Plant and machine operators, and assemblers	M	2133	11,2	0,1	5	20	10,7	0,9	0	44	12,2	0,3	3,0	37,8
	F	515	11,3	0,2	5	20	12,2	0,9	0	42	10,9	0,3	3,8	31,3
Elementary occupations	M	1130	11,3	0,1	5	17	10,9	1,0	0	41	11,0	0,3	2,5	31,2
	F	1960	11,0	0,2	5	20	10,2	1,0	0	43	9,7	0,3	2,9	39,8

45. As a brief conclusion, these statistics show that the unadjusted gender wage gap shows very large differences according to economic activities and occupations that are not due to the levels of education and work experience between men and women since it is demonstrated that women tend to earn less than men for doing the same job.

4. Results obtained for the Malmquist and pseudo–Hicks Moorsteen Indices

46. Using the models described in Section 2, based on a comparison of male and female observations, we have calculated the proposed MI and pseudo-HMI that represent the gender pay gaps for each economic activity and occupation. Table 4 presents the results.

Table 4. Values of the Malmquist index by economic activity and occupation (with VRS assumption, input and output-oriented)

	$Unadjusted\ GPG$	MI_I	MI_O	$Pseudo\ HMI$
Economic Activity				
Agriculture, forestry and fishing	0,9	0,992	1,031	1,102
Manufacturing	10,1	0,940	1,105	1,085
Electricity, gas, steam and air conditioning supply	14,1	0,974	1,123	1,074
Water supply; sewerage, waste management and remediation	8,0	0,858	1,140	1,153
Construction	2,0	0,885	1,099	1,114
Wholesale and retail trade; repair of motor vehicles	7,7	0,957	1,077	1,061
Transportation and storage	1,6	0,913	1,110	1,103
Accommodation and food service activities	4,6	0,938	1,061	1,064
Information and communication	10,3	0,960	1,122	1,081
Financial and insurance activities	11,6	0,974	1,119	1,072
Real state activities	4,8	0,948	1,050	1,053
Professional, scientific and technical activities	9,3	0,963	1,100	1,068
Administrative and support service activities	6,3	0,953	1,057	1,053
Public administration and defence; compulsory social security	6,1	0,937	1,095	1,081
Education	15,3	0,957	1,143	1,092
Human health and social work activities	8,5	0,989	1,090	1,050
Arts, entertainment and recreation	7,1	0,941	1,106	1,084
Other service activities	11,2	0,984	1,103	1,059
Occupation				
Managers	10,4	0,976	1,132	1,077
Professionals	7,8	0,952	1,130	1,090
Technicians and associate professionals	8,2	0,931	1,096	1,085
Clerical support workers	5,9	0,957	1,075	1,060
Service and sales workers	11,4	0,992	1,140	1,072
Skilled agricultural, forestry and fishery workers	14,5	0,921	1,110	1,098
Craft and related trades workers	11,3	0,981	1,106	1,062
Plant and machine operators, and assemblers	10,7	0,959	1,119	1,080
Elementary occupations	11,9	1,018	1,100	1,039

47. In the 18 economic activities and 9 occupations analyzed, considering the level of education and work seniority, the value of the pseudo-HMI is higher than one meaning general gender discrimination. This unadjusted GPG varies from 1.9% (agriculture, forestry, fishing) to 15.3% for (water supply, sewerage, waste management and remediation) and varies from 3.9% (elementary occupations) to 9.8% (skilled agricultural, forestry and fishery workers).

48. Concerning the input-oriented MI, which represents the "sticky floor" effect, it is always in disfavour of women except for elementary occupations. It is especially high for water supply, sewerage, waste management and remediation, construction, transportation and storage, technicians and associate professionals and skilled agricultural workers.

49. The output-oriented MI, representing the "glass ceiling" effect, shows discrimination against women as well. It is especially high in electricity, gas, steam and air conditioning supply, information and communication, financial and insurance activities, education, transport and storage.

50. Finally, the "glass ceiling" effect is over the "sticky floor" effect in all occupations and economic activities except for real estate and accommodation and food service activities.

5. Conclusions

51. Accurately measuring the gender pay gap is important in order to evaluate how far we are from the ideal of equal pay for work of equal value. With this article we contribute measuring the gender pay gap with a non-parametric method. The use of DEA to calculate the Malmquist Index in input as a measure of the "sticky floor" and the Malmquist Index in output as a measure of the "glass ceiling", has allowed us to, consequently, produce a pseudo-Hicks-Moorsteen Index that can be viewed as a complete measure of the gender pay gap. The calculations were replicated to different economic activities or sectors and different occupations, to capture the effects of occupational and economic activity segregation.

52. The efficiency analysis reveals important differences in the level of pay between female and male workers. Almost all economic activities and occupations in France suffer from a gender pay gap, even if women are mostly more educated than men.

53. Efforts to close the gender pay gap include enforcing equal pay laws, increasing transparency in pay practices, promoting women into leadership positions, and providing family-friendly benefits. However, progress has been slow, and in France, the gap remains significant.

54. Even though the differences in the salary between male and female workers with the same level of educations, seniority and economic activities or occupation demonstrated in this article, we look forward to producing future studies with different methodology. Firstly, we would like to consider other models including several outputs. Indeed, individuals may try to maximise their hourly wages but also their free time to get a balance between professional and family life. Thus, we propose to consider a second model with two outputs: the hourly wages and the leisure time, i.e., hours not worked.

55. We also propose as future research to measure gender wage gap thanks to the Hicks Moorsteen Index. This index is composed of two specific Malmquist Indices. Those indices are computed by considering the distance between the situation of a female with the situation of an artificial point that is the situation of a male which will have exactly the inputs of the given female. The situation of one female is then compared with the situation of all male which have artificially the same inputs. The method is replicated for all the female of the sample.

56. We finally propose to apply the shapely decomposition to the Malmquist Indices or Hickes-Moorsteen indices to measure the contribution of various factors of the gender wage gap.

References

- Albrecht, J., A., Vroman, S. (2009). “Counterfactual distributions with sample selection adjustments: Econometric theory and an application to the Netherlands”, Labour Economics. 16(4), 383-396.
- Amado, C. A. F., Santos, S. P., Sao Jose, J. M. S. (2018). “Measuring and decomposing the gender pay gap: A new frontier approach”. European Journal of Operational Research. 271(1), 357–373.
- Bowlin W. and C. Renner (2008). “Assessing gender and top-management-team pay in the SP mid-cap and small-cap companies using data envelopment analysis”. European Journal of Operational Research. 185, 430-437.
- Arulampalam, W., Booth, A., Bryan, M. (2007). “Is there a glass ceiling over Europe? Exploring the gender pay gap across the wage distribution”. Industrial and Labor Relations Review. 60(2), 163–186.
- Badel, A., Peña, X. (2010). Decomposing the Gender Wage Gap with Sample Selection Adjustment: Evidence from Colombia. SSRN Electronic Journal. Georgetown University. 10.2139/ssrn.1699771.
- Bishop J., A. Grodner, H. Liu, J. Chiou (2007). “Gender earnings differentials in Taiwan: A stochastic frontier approach”. Journal of Asian Economics. 18(6), 934-945.
- Blinder, A. (1973). “Wage discrimination: reduced form and structural estimates”. Journal of Human Resources. 8, 436–455.
- Borráz, F., Robano, C. (2010). “Brecha salarial en Uruguay”. Revista de Análisis Económico. 25(1), 49–77.
- Camanho, A. S., & Dyson, R. G. (2006). “Data envelopment analysis and Malmquist indices for measuring group performance”. Journal of Productivity Analysis, 26, 35–49. Caves, D. W.
- Christensen, L. R., & Diewert, W. E. (1982). “The economic theory of index numbers and the measurement of input, output, and productivity”. Econometrica. 50 (6), 1393–1414.
- Charnes, A., Cooper, W. W., & Rhodes, E. (1978). “Measuring the efficiency of decision-making units”. European Journal of Operational Research. 2, 429–444.
- Carrillo, P., Gandelman, N. & Robano, V. (2014). “Sticky floors and glass ceilings in Latin America”. Journal of Economic Inequality. 12, 339–361.
- Cotter, D. A., Hermsen, J. M., Ovadia, S., & Vanneman, R. (2001). “The glass ceiling effect”. Social Forces. 80(2), 655–681.
- Díaz A., M. and Sánchez, R. (2011), "Gender and potential wage in Europe: a stochastic frontier approach". International Journal of Manpower, 32(4), 410-425.
- Fall F., H. Tchakoute, A. Vanhems, & L. Simar (2021). “Gender effect on microfinance social efficiency: A robust nonparametric approach”. European Journal of Operational Research. 295(2), 744-757.
- Garcia-Prieto, C. and Gómez-Costilla, P. (2017), "Gender wage gap and education: a stochastic frontier approach". International Journal of Manpower. 38(3), 504-516.
- International Labour Organization (2019). Global Wage Report. Geneva: International Labour Office. Available at: https://cutt.ly/gJCHkaW (accessed for the last time on 21/009/2022).
- Malmquist, S. (1953). “Index numbers and indifference surfaces”. Trabajos De Estatistica, 4, 209–242.
- Maume, D. J. (1999). “Glass ceilings and glass escalators”. Work and Occupations. 26(4), 483–509.
- Oaxaca, R. (1973). “Male female wage differentials in urban labor markets”. International Economic Review. 14(3), 693–709.
- Weichselbaumer, D. and R. Winter-Ebmer (2005). “A meta-analysis of the international gender wage gap”. Journal of Economic Surveys. 19 (3), 479-511.