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OWA SALARY BY GENDER IN MEXICO

Abstract. *To know how to predict wages by gender and by region is a vital issue for the economic development of a country, because many companies require salary evaluation to determine the human capital they will require, to have the most qualified people, improve the profitability of the company and optimize economic and human resources. In addition to it, today we observe that salaries are in favor of men, regardless of their educational level, in particular in Mexico this situation occurs, subsequently we want to know what wages would be in the future by determining gender, so that we can undertake new policies that allow for equity. Using Ordered Weighted Averaging (OWA), the Ordered Weighted Averaging–Weighted Average OWAWA, the Induced Ordered Weighted Averaging (IOWA), Generalized Ordered Weighted Averaging (GOWA) and introducing a new operator OWA Salary (OWAS), IGOWA Salary, and Quasi IOWA Salary, we are able to create salary predictions determined by gender in Mexico.*

Keywords: *OWA Operators, Salary, Gender, Weighting Methods, Financial Decision Making*

JEL Classification: C44, D63, D81, G11

1. Introduction

One of the problems around the economy is to analyse the salary by gender, as well as the difference between cities, taking into account policies that comply with possible predictions. These predictions can be observed by the operator OWA Ordered Weighted Averaging (R. R. Yager, 1988). This paper is focused on the abovementioned Ordered Weighted Averaging–Weighted Average OWAWA (Merigó, Guillén, & Sarabia, 2015), the Induced Ordered Weighted Averaging

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IOWA (Beliakov & James, 2011), Generalised Ordered Weighted Averaging GOWA (Merigó & Gil-Lafuente, 2009), the IGOWA operator and the QIOWA operator (Merigó & Gil-Lafuente, 2009) Given that OWA operator has many applications in economics and finance (Merigó & Gil-Lafuente, 2010; Merigó & Casanovas, 2011; Merigó, Carral, & Castillo, 2012; Merigó & Yager, 2013; (Emrouznejad & Marra, 2014; Blanco-Mesa, Merigó, & Kacprzyk, 2016; Alfaro-García, Merigó, Gil-Lafuente, & Kacprzyk, 2018; León-Castro, Avilés-Ochoa, & Merigó, 2018).

In this article, the focus is on the salary of women and men in Mexico. The salary differences between men and women are presented by industry and occupations (Blau & Kahn, 2007), in many countries women earn less than men with the same characteristics in their jobs, like New Zealand (Sin, Stillman, & Fabling, 2020) and the United States (Mcelhaney & Smith, 2017). These problems have been studied by many international organisations such as the Organisation for Economic Co-Operation and Development, UN Women, and so on (International Labour Organisation, 2018). Some research suggests that there are factors that affect women's salary, such as physical, educational, and experience differences (Blau & Kahn, 2007). Women earn 18% less than men (Brynin, 2017), in some countries 40% less than men. Closing the gender pay gap is one of the priorities of our days (Rubery & Koukiadaki, 2016).

The wage gap that persists in all the states of Mexico is a factor that must be analysed, in a way that allows us to find better public policies. In recent years, there has been not only the participation of women in the household economy, but even a change of roles, in which the woman is the one who provides at home everything necessary for sustenance. The woman has relatively few years in those who have been inserted in university studies and, more strongly in the workplace, gender roles in ancient times were established where the man was the provider and the woman stayed at home to care for the children (Saldívar Garduño et al., 2015).

Today, many women are heads of the family in Mexico; they take on the responsibility of running the home, in addition to educating their children (González & Sánchez, 2016). We know that most women in the world are at a disadvantage compared to men in terms of wages (International Labour Organization, 2018), but in Mexico it is important to know what the disadvantages are and what factors influence their salary, depending on their human capital. It is true that this problem is a factor in the social sphere, but it is possible to approach it from predictions with OWA operators.

2. Preliminaries

In this section, we briefly review some basic concepts that will be used throughout the paper. We analyse the OWA operators, OWAWA operator, GOWA operator, and IOWA operator.

2.1. OWA operator

An OWA operator (R. R. Yager, 1988) that helps us verify the parameterised family of aggregation operators, provides a maximum and a minimum that include the arithmetic mean; it can be defined as follows.

Definition 1: Let I denote the closed interval $[0,1]$. An OWA operator of dimension n, is a mapping:

$$\vartheta_1 : \mathbb{R}^n \rightarrow \mathbb{R} \quad (1)$$

$$(a_1, \ldots, a_n) \mapsto \sum_{j=1}^{n} w_j \, b_j \quad (2)$$

With an associated weithing vector $W = (w_1, \ldots w_n) \in I^n$ such that

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the a_i
3. $w_i \in [0,1]$

2.2. OWAWA operator

The OWAWA operator combines the OWA operator and the WA in the same formulation, it can be defined as follows:

Definition 2: Let I denote the closed interval $[0,1]$. An OWAWA operator of dimension n is a mapping:

$$\vartheta_2 : \mathbb{R}^n \rightarrow \mathbb{R} \quad (3)$$

$$(a_1, \ldots, a_n) \mapsto \sum_{j=1}^{n} \tilde{v}_j \, b_j \quad (4)$$

With an associated weighting vector $W = (w_1, \ldots, w_n) \in I^n$ such that:

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the a_i, i.e. for each $(a_1, \ldots, a_n) \in \mathbb{R}^n$ there is a permutation $\sigma \in S_n$ such that $b_i = a_{\sigma(i)}$
3. $v_i = w_{\sigma(i)}$ and $\tilde{v}_i = \beta w_i + (1-\beta) v_i$ for some $\beta \in I$

2.3. IOWA operator

The IOWA operator is a representation and an extension of the OWA operator, in this case the reordering step is given by induced variables. The IOWA operator contains maximum, minimum, and the average criteria. We are going to define it.

Definition 3: Let I denote the closed interval $[0,1]$. An IOWA operator of dimension n is a mapping:

$$\vartheta_3 : \mathbb{R}^{2n} \rightarrow \mathbb{R} \tag{5}$$

$$(\langle u_1, a_1 \rangle, \ldots, \langle u_n, a_n \rangle) \mapsto \sum_{j=1}^{n} w_j \, b_j \tag{6}$$

With an associated weighting vector $W = (w_1, \ldots, w_n) \in I^n$ such that:

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the a_i, i.e. for each $(a_1, \ldots, a_n) \in \mathbb{R}^n$ and the a_i value of the OWA pair $\langle u_i, a_i \rangle$

2.4. GOWA operator

The generalised ordered weighted averaging operator introduced in 2004 by Yager (R. Yager et al., 2004), that adds to the OWA operator an additional parameter controlling the power to which the argument values are raised. In the following, we are going to define it.

Definition 4: Let I denote the closed interval $[0,1]$. A GOWA operator of dimension n, is a mapping

$$M : \mathbb{R}^n \rightarrow \mathbb{R} \tag{7}$$

$$M(a_1, \ldots, a_n) = \left(\sum_{j=1}^{n} w_j b_j^{\lambda} \right)^{\frac{1}{\lambda}} \tag{8}$$

With an associated weighting vector $W = (w_1, \ldots w_n) \in I^n$ such that

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the a_i
3. $M(a_1, \ldots, a_n) = \left(W^T B^{\lambda} \right)^{\frac{1}{\lambda}}$

With a parameter $\lambda \in \mathbb{R}/\{0\}$.

3. OWA salary operator

3.1. OWAS operator

The OWA Salary operator is an extension of the OWA operator, but in this particular case we take a data set related to the salary of individuals. We can define it as follows.

Definition 5: Let I denote the closed interval $[0,1]$. An OWAS operator of dimension n, is a mapping

$$OWAS: \mathbb{R}^n \to \mathbb{R} \tag{9}$$

$$(s_1, \ldots, s_n) \mapsto \sum_{j=1}^{n} w_j b_j \tag{10}$$

With an associated weithing vector $W = (w_1, \ldots w_n) \in I^n$ such that

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the s_i and s denote the salary
3. $w_i \in [0,1]$

Example 1: Let the following collection of salary $S = (20, 57, 45, 25)$ and $W = (0.3, 0.5, 0.1, 0.1)$, calculating OWAS

$$OWAS(S) = (57 \times 0.3) + (45 \times 0.5) + (25 \times 0.1) + (20 \times 0.1) = 44.1$$

The characteristics of OWAS operator can be seen as follows:

Theorem 1: Monotonic: if $s_i \geq d_i$ for all i, then:

$$OWAS(s_1, \ldots s_n) \geq OWAS(d_1, \ldots d_n).$$

Proof: Trivial and therefore omitted.

Theorem 2: Commutativity: If we assume that $OWAS$ is an operator, then,

$$OWAS(s, d) = OWAS(d, s) \tag{11}$$

Proof: Trivial and therefore omitted.

Theorem 3: Boundedness: Let f be the $OWAS$ operator, then,

$$\min\{|s_i - d_i|\} \leq f(s_1, \ldots s_n) \leq \max\{|s_i - d_i|\} \tag{12}$$

Proof: Trivial and therefore omitted.

Theorem 4: Idempotency: If we assume that $OWAS$ is an operator, then, $OWAS(1, s) = s$

Proof: Trivial and therefore omitted.

Theorem 5: No negativity: Let the function f be the $OWAS$ operator, then,

$$f\left(s_1,\dots s_n\right)\geq 0 \tag{13}$$

Proof: Trivial and therefore omitted.

3.2. Families of the OWAS operator

The relationship between OWA operators and linguistic quantifiers was studied by Yager (1993).

Definition 6: Let W_* be the weighting vector that has $W_n=1$ and $W_j=0$ for all $j\neq n$. Let W^* be the weighting vector which has $W_1=1$ and $W_j=0$ for all $j\neq 1$.

Theorem 6: Let B be an arbitrary ordered input vector, and W a weighting vector, then:

$$(W_*)^T B\leq W^T B\leq (W^*)^T B \tag{14}$$

Proof: Trivial and therefore omitted.

Definition 7: Let F^* and F_* denote the OWAS operator with W^* and W_* respectively as their weighting vectors. If $S=\left\langle s_1,\dots s_n\right\rangle$ are the criteria values, then for any operators F,

$$F_*(S)\leq F(S)\leq F^*(S) \tag{15}$$

Then F_* and F^* are the lower and upper bound on the aggregation taking the OWAS operator.

Theorem 7: Let $s_1,\dots s_n$ be a collection of numbers in the $\left[0,1\right]$, then:

$$F_*(s_1,\dots s_n)=Min_j(s_j) \tag{16}$$

$$F^*(s_1,\dots s_n)=Max_j(s_j) \tag{17}$$

Proof: Trivial and therefore omitted.

3.3. OWAWAS

We combine the OWA operator and the WA in the same formulation with salaries, it can be defined as follows.

Definition 8: Let I denote the closed interval $\left[0,1\right]$. An OWAWAS operator of dimension n is a mapping:

$$OWAWAS\colon \mathbb{R}^n\rightarrow\mathbb{R} \tag{18}$$

$$(s_1,\ldots,s_n)\mapsto\sum_{j=1}^{n}\tilde{v}_j b_j \qquad (19)$$

With an associated weighting vector $W=(w_1,\ldots,w_n)\in I^n$ such that:

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the s_i, i.e. for each $(s_1,\ldots,s_n)\in\mathbb{R}^n$ there is a permutation $\sigma\in S_n$ such that $b_i = s_{\sigma(i)}$ and s denote the salary.
3. $v_i = w_{\sigma(i)}$ and $\tilde{v}_i=\beta w_i+(1-\beta)v_i$ for some $\beta\in I$.

3.4. IOWAS

The IOWA operator with salaries is a representation and an extension of the OWAS operator; in this case the reordering step is given by induced variables. The definition is as follows.

Definition 9: Let I denote the closed interval $[0,1]$. An IOWAS operator of dimension n is a mapping:

$$IOWAS:\mathbb{R}^{2n}\to\mathbb{R} \qquad (20)$$

$$(\langle u_1,s_1\rangle,\ldots,\langle u_n,s_n\rangle)\mapsto\sum_{j=1}^{n} w_j b_j \qquad (21)$$

With an associated weighting vector $W=(w_1,\ldots,w_n)\in I^n$ such that:

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the j-th largest of the s_i, i.e. for each $(s_1,\ldots,s_n)\in\mathbb{R}^n$ and the s_i value of the OWAS pair $\langle u_i,s_i\rangle$ and s denote the salary.

3.5. GOWAS

The GOWAS operator adds to the OWA operator an additional parameter controlling the power to which the argument values are raised for the salaries. It can be constructed by the following process.

Definition 10: Let I denote the closed interval $[0,1]$. A GOWAS operator of dimension n, is a mapping

$$GOWAS:\mathbb{R}^{n}\to\mathbb{R} \qquad (22)$$

$$GOWAS(s_1,\ldots,s_n)=\left(\sum_{j=1}^{n} w_j b_j{}^{\lambda}\right)^{\frac{1}{\lambda}} \quad (23)$$

With an associated weithing vector $W=(w_1,\ldots w_n)\in I^n$ such that

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the jth largest of the s_i and s denote the salary.
3. $w_i \in [0,1]$
4. $M\left(s_1,\ldots,s_n\right)=\left(W^T B^{\lambda}\right)^{\frac{1}{\lambda}}$

With a parameter $\lambda \in \mathbb{R}/\{0\}$.

4. IGOWAS operator

The induced generalised OWAS (IGOWAS) operator is a representation of an extension to the GOWAS operator. In this particular operator we reorder the step of the IGOWAS operator, but it is not developed with the values of the arguments a_i, it is represented as u_i. The definition is as follows.

Definition 11: Let I denote the closed interval $[0,1]$. An IGOWAS operator of dimension n, is a mapping

$$IGOWAS: \mathbb{R}^n \rightarrow \mathbb{R} \quad (24)$$

$$IGOWAS(\langle u_1,s_1\rangle,\langle u_2,s_2\rangle,\cdots,\langle u_n,s_n\rangle)=\left(\sum_{j=1}^{n} w_j b_j{}^{\lambda}\right)^{\frac{1}{\lambda}} \quad (25)$$

With an associated weighting vector $W=(w_1,\ldots w_n)\in I^n$ such that

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the jth largest of the s_i and s denote the salary, s_i is the value of the IGOWA pair $\langle u_i, s_i\rangle$ having the jth largest u_i and this one is the order inducing variable.
3. $w_i \in [0,1]$

With a parameter $\lambda \in \mathbb{R}/\{0\}$.

A generalisation of the IGOWAS operator is using quasi-arithmetic means, the Quasi-IOWAS operator can be defined as follows:

Definition 12: Let I denote the closed interval $[0,1]$. A Quasi-IOWAS operator of dimension n, is a mapping

$$QIOWAS: \mathbb{R}^n \rightarrow \mathbb{R} \tag{26}$$

$$QIOWAS(\langle u_1, s_1 \rangle, \langle u_2, s_2 \rangle, \cdots, \langle u_n, s_n \rangle) = g^{-1}\left(\sum_{j=1}^{n} w_j g(b_j)\right) \tag{27}$$

With an associated weithing vector $W = (w_1, \ldots w_n) \in I^n$ such that

1. $\sum_{i=1}^{n} w_i = 1$
2. b_j is the jth largest of the s_i and s denote the salary, s_i is the value of the QIOWA pair $\langle u_i, s_i \rangle$ having the jth largest u_i and this one is the order inducing variable.
3. $g(b)$ is a general strictly monotone function.
4. $w_i \in [0,1]$

With a parameter $\lambda \in \mathbb{R}/\{0\}$.

We include particular cases of the Quasi-IOWAS operator, the trigonometric IOWAS is found when $g_1(t) = sin((\pi/2)t)$, $g_2(t) = cos((\pi/2)t)$, $g_3(t) = tan((\pi/2)t)$, then the trigonometric IOWA functions are:

$$QIOWAS(\langle u_1, s_1 \rangle, \langle u_2, s_2 \rangle, \cdots, \langle u_n, s_n \rangle) = \frac{2}{\pi} arcsin\left(\sum_{j=1}^{n} w_j \, sin(\frac{\pi}{2} b_j)\right) \tag{28}$$

$$QIOWAS(\langle u_1, s_1 \rangle, \langle u_2, s_2 \rangle, \cdots, \langle u_n, s_n \rangle) = \frac{2}{\pi} arccos\left(\sum_{j=1}^{n} w_j \, cos(\frac{\pi}{2} b_j)\right) \tag{29}$$

$$QIOWAS(\langle u_1, s_1 \rangle, \langle u_2, s_2 \rangle, \cdots, \langle u_n, s_n \rangle) = \frac{2}{\pi} arctan\left(\sum_{j=1}^{n} w_j \, tan(\frac{\pi}{2} b_j)\right) \tag{30}$$

5. OWA salary by gender

To predict salaries, we analyse the 2018 National Survey of Household Income and Expenditure (ENIGH) of the National Institute of Statistics and Geography (INEGI), it is necessary to do data mining to divide the women's salary from the men´s one. We also select the different states of Mexico, and the different educational levels. When we finish we can start to calculate the operators. Now in this section we are going to present step by step how to calculate them.

5.1. Data mining and weighting vector

In order to find the prediction about salary gender, it is important to know that it is going to depend on the kind of data basis that we are going to check.

Step 1. Identify the salaries found in an official database and choose the state or region you want to work with.

Step 2. Analyse the data and divide men and women salaries.

Step 3. Calculate the weighting vector $W = (w_1, \dots w_n)$

$$w_i = \frac{e^{-\left[(i-\mu_n)^2/2\sigma_n^2\right]}}{\sum_{j=1}^{n} e^{-\left[(i-\mu_n)^2/2\sigma_n^2\right]}}, \qquad i = 1, 2, \dots n \tag{31}$$

For the different methods to obtain the weighting vector, we can see Zeshui (Zeshui, 2005).

Step 4. Sort salaries from highest to lowest.

Step 5. Use the OWAS operator to calculate the prediction

Step 6. Take a decision based on the results found using different aggregation operators.

5.2. Selecting Mexico´s salary

Step 1. Identify salaries in this case in the National Survey of Household Income and Expenses in the National Institute of Statistic and Geography, we focus only on the Home Concentrate table.

Step 2. The indicator 1 for men and 2 for women needs to be filtered.

Step 3. Calculate the weighting vector, since we are taking a database of thousands of data, we will give an idea of the weights obtained: $W_M = (0.00366065, 0.00313753, \dots, 0.00052727)$ and $W_w = (0.00349348, 0.00389097, \dots, 0.00248421)$

Step 4. Salary for men from highest to lowest $S_M = (121323.83, 110436.38, \dots, 552.91)$ and for women $S_w = (99825.42, 98117.74, \dots, 1741.69)$

Step 5. Calculate OWAS for men and women, we obtain: $OWAS(S_M) = \$24,000.13$ and $OWAS(S_W) = \$18,419.58$ as we can see there exists a gender wage gap. Let us check the other operators. For $IOWAS(S_M) = \$23,822.11$ and $IOWAS(S_W) = \$18,495.39$ taking the induced vector as giving priority to men and women who have postgraduate studies.

Table 1. OWAWA Salary and GOWA Salary for mexican men

β	$OWAWAS(S_M)$	λ	$GOWAS(S_M)$
0	24693.7486	-1	14927.83571

β	$OWAWAS(S_M)$	λ	$GOWAS(S_M)$
0.2	24555.0253	0	1
0.5	24346.9405	1	24000.13236
0.8	24138.8556	2	30410.38575
1	24000.1324	3	37323.74663

Source: Own Elaboration

Table 2. OWAWA Salary and GOWA Salary for mexican women

β	$OWAWAS(S_W)$	λ	$GOWAS(S_W)$
0	18680.3996	-1	13997.13
0.2	18628.2356	0	1
0.5	18549.9896	1	18419.58
0.8	18471.7436	2	23574.53
1	18419.5796	3	29319.95

Source: Own Elaboration

Table 3. QIOWA Salary for mexican men and women

	QUIOWAS MEN	QIOWAS WOMEN
Equation 28	-45.309	-13.091
Equation 29	1.098	0.637
Equation 30	0.061	0.144

Source: Own Elaboration

Step 6. We must analyse state by state and perhaps region by region, in a way that allows us to make better decisions in our policies.

6. Conclusions

This paper has introduced the salary in many operators, the OWA Salary, an extension of OWA operator, this operator can be used with IOWAS operator, OWAWAS operator, GOWAS operator, IGOWAS operator and QUASI-IOWAS operator. In this particular investigation we divide men's salary and women's salary; then we can analyse maximum and minimum salaries, generalised means and order inducing variables in the reordering of the arguments.

These operators allow predictions about future salaries, taking different choices depending on what we want to predict if more positive arguments or negative ones. These predictions are an essential element for political and social decision making.

Upcoming research can be done for a specific region or for the comparison of various countries in the world, and take other operators to predict different scenes.

Mexico requires a solid strategy to advance its economy, human capital, and in particular women, is one of the factors that triggers this growth in most countries, for which the country must prioritise continuing to support its human capital resource. Mexico has not presented a strong economic development, nor is it inclusive, so that Mexican families can benefit. There are economic sectors that have lagged behind, and that have been affected by corruption, rigorous regulations, among other factors. (Organización para la Cooperación y el Desarrollo Económicos (OCDE), 2017).

Furthermore, human capital is an issue that is becoming increasingly important within countries, since it has been viewed as one of the factors that influence the economic development of a country. Likewise, it has been observed that teaching throughout the life of the individual will allow, in the event of unemployment, to more easily get into the labour force. From an economic point of view, education is the increase of knowledge, as well as the qualifications and understanding of individuals as a whole. So, the economics of education will deal with how it is invested and the factors that influence students, people, and teachers. Producing education is a not so trivial issue, as well as the provision of its educational services, will depend on geographical, ethnic, institutions, public policies, educational supply, and demand, among many other issues. (López & Almagro, 2005).

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