Applying Neutrosophic Chi-Square Test and Social Structures to Analyze Gender Parity

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Abstract

This paper examines the disparities in job opportunities and social prosperity based on gender within Peruvian universities, particularly focusing on the Universidad Peruana Los Andes during 2021-2022. Utilizing Neutrosophic Social Structures and the Neutrosophic 2-tuples Technique, we statistically analyze the entrenched biases that categorize careers by gender, contributing to power imbalances and unequal employment rates between men and women. By modeling student data through intervals or neutrosophic numbers as per Smarandache's theory, we address the unique engagement of each student with their academic environment. Neutrosophic contingency tables are employed to present this data, and a neutrosophic chi-square test is applied to examine the correlation between students' gender and their major fields of study, which include Administrative and Accounting Sciences, Health Sciences, Law and Political Sciences, Engineering Sciences, and Pedagogical Sciences. This neutrosophic approach allows for a nuanced understanding of the indeterminate and complex nature of social phenomena, providing a clearer insight into gender parity in academic professional development.

Keywords: Neutrosophic Social Structure; (t,i,f)-Neutrosophic structure model; Neutrosophic Statistics; Neutrosophic number; Neutrosophic contingency table; Neutrosophic chi-square test; Higher education; Gender parity.

1. Introduction

Universities play a very important role in promoting greater labor insertion of their students and graduates. To build a more solid insertion, there must be an adequate curricular structure in professional careers so that new knowledge, skills, and attitudes will be developed, and thereby complement competencies through the university's pre-professional practices. However, Peruvian universities in current years still suffer from certain gender stereotypes that hinder the personal fulfillment of students once they graduate.

Gender issues have gained relevance in all social aspects in recent times. Although the bias between men and women has decreased in recent years and policies and initiatives have been adopted to reduce existing gaps, gender differences and barriers in the professional development of women persist. Disparities related to access to management positions, the increase in the unemployment rate, the lack

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of participation in the market, and the existence of multiple inhibiting factors and stereotypes that repress women's career aspirations and opportunities continue to be a reality.

In addition, the 2020 health crisis generated a significant impact on the performance of women's labor indicators, as well as the contraction of female participation and employment rates, which had been growing since 2015 and showed progress in incorporation of women in the labor market in Latin America.

Although women's entry into the labor market has increased considerably, linked to higher levels of study, the same market has been responsible for hindering female advancement by limiting women's access to management and decision-making positions. Various studies have focused on explaining gender disparities in organizational leadership and analyzing the multiple inhibiting factors that repress women's aspirations and opportunities since women occupy only 29% of senior leadership positions worldwide. This figure is considerably reduced in some Latin American countries.

In the global political arena, only 11% of the world's countries are women making the most important social and economic decisions in their country. Only 5% (24) of the Fortune 500 CEOs are women, and that number rises to only 25% as board members, even though women hold nearly half of the world's jobs.

Among the inhibiting factors and stereotypes that perpetuate the gender gap, is the lack of inclusion related to the insufficient representation of women in management positions. There is lack of promotion associated with the existence of biases in selection processes, where women are notably less confident in fulfilling their leadership ambitions. Also we can observe the increase in the domestic burden explained by the lack of conciliation between household chores and work responsibilities, which leads women to interrupt their education. Women are penalized in wages for having children or increase their unpaid care time, which restricts their time to enter the workforce.

Moreover, the existence of unconscious biases and internal barriers is evident that lead to overestimating the performance of men and underestimating that of women, as well as the prevalence of traditional leadership styles associated with cultural stereotypes, and the horizontal and vertical segregation of work.

Among the social gender stereotypes that persist even today in Peruvian universities is that certain university courses are for men and other courses are for women, [1]. We consider that these differences also influence the limitations that women have when performing a specific job.

This paper proposes to determine if this last gender stereotype persists at the Universidad Peruana Los Andes, in the province of Huancayo. To do this, the total number of students who are part of each of the courses is analyzed. The study included all graduate students in the 2021-2022 academic years at this university.

To achieve greater accuracy in the results, we consider data in the form of intervals instead of a specific number of students classified by each major. We want to capture the complexity of studying at a university. Each student constitutes a different case and their degree of belonging and involvement in university processes is not the same for all. Some students have remained in university classrooms almost uninterruptedly throughout their years of study, while the other extreme is that of students who have been part of the university intermittently, because they have come from other higher education centers or because they have accessed a distance education course. That is why we have represented this characteristic with the help of an interval of the number of students modeled in the form of neutrosophic numbers, [2, 3].

Specifically, we have adopted Smarandache's theory of Neutrosophic Social Structures, where society is understood as a structure governed by laws or axioms that are not dichotomous and that present a degree of uncertainty and indeterminacy [4, 5]. We located these data in the form of neutrosophic numbers in a contingency table of five types of careers (Administrative and Accounting Sciences, Health Sciences, Law and Political Sciences, Engineering Sciences and Pedagogical Sciences) versus the gender of graduated students by every type of career. This work aims to establish whether there is independence or not between these two variables, by applying the neutrosophic chi-square test proposed in [6].

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This paper continues with section 2 where we summarize the theory of Neutrosophic Social Structures, neutrosophic numbers and Neutrosophic statistics. Section 3 is dedicated to presenting the results of the carried out study. The conclusions of the paper appear in section 4.

2. Related Work

A. (t,i,f)-structures and Neutrosophic numbers

A (t,i,f)-structure is composed of one space S endowed with a set of axioms (or laws) acting (governing) on it, such that the space or at least one of its axioms has an indeterminacy. *t* represents the degree of truthfulness, *i* represents the degree of indeterminacy, and *f* represents the degree of falseness [7, 8].

This theory was created to apply in mathematical branches like Algebra and Geometry. However, soon F. Smarandache recognized its applicability in sociological sciences. That is, he recognized that the different points of view of all the individuals in society have as a consequence complex relationships in society itself, which causes indeterminacy.

Specifically, we are dealing with I-Neutrosophic Structures, as we explain further.

The following are some important concepts that serve as the basis of this theory:

Definition 1 ([2, 3]): A *neutrosophic number* N is defined as a number as follows:

$$N = d + I \quad (1)$$

Where d is called the *determined part* and I is called the *indeterminate part*.

Given $N_1 = a_1 + b_1 I$ and $N_2 = a_2 + b_2 I$ two neutrosophic numbers, some operations between them are defined as follows:

$N_1 + N_2 = a_1 + a_1 + (b_1 + b_2)I$ (Addition);

$N_1 - N_2 = a_1 - a_1 + (b_1 - b_2)I$ (Difference),

$N_1 \times N_2 = a_1 a_2 + (a_1 b_2 + b_1 a_2 + b_1 b_2)I$ (Product),

$\frac{N_1}{N_2} = \frac{a_1 + b_1 I}{a_2 + b_2 I} = \frac{a_1}{a_2} + \frac{a_2 b_1 - a_1 b_2}{a_2(a_2 + b_2)} I$ (Division).

Smarandache also defined types of truthfulness, indeterminacy and falsity symbolically beyond the T, I and F. He called this *refinement*, where T is divided into $T_1, T_2, \dots, T_p$; I into $I_1, I_2, \dots, I_q$; and F into $F_1, F_2, \dots, F_r$, which depend on the problem at hand. Specifically, he extended the numbers given in Equation 1, to represent the Refined Neutrosophic Numbers.

Definition 2 ([9]): Given $I_1, I_2, \dots, I_q$, with $q \geq 1$, a *Refined Neutrosophic Number* is obtained from the previous set as $N_q = a + b_1 I_1 + b_2 I_2 + \cdots + b_q I_q$, where a is the determinate part and $b_j I_j (j = 1,2, \dots, q)$ are the indeterminate parts, such that $a, b_1, b_2, \dots, b_q$ are real or complex numbers.

Some fulfilled properties are shown below:

- $m I_k + n I_k = (m + n) I_k$,
- $0 I_k = 0$,
- $I_k^n = I_k$,
- I_k / I_k =undefined,
- $I_j I_k$ with $j \neq k$ is defined depending on the problem being treated.

B. Neutrosophic statistics

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Neutrosophic statistics refers to a set of data, such that the data or a part of it is indeterminate to some degree, and to the methods used to analyze these data [10-16].
In classical statistics every datum is determined; this is the distinction between neutrosophic statistics and classical statistics. In many cases, when the indeterminacy is zero, the neutrosophic statistics coincide with the classical statistics. Neutrosophic measurement can be used to measure indeterminate data. *Neutrosophic statistical methods* will allow us to interpret and organize neutrosophic data (data that may have some indeterminacy) to reveal underlying patterns. Many approaches can be used in neutrosophic statistics.
In *neutrosophic probability*, indeterminacy is different from randomness. While classical statistics is concerned solely with randomness, neutrosophic statistics is concerned with both randomness and especially indeterminacy.
Neutrosophic descriptive statistics consists of all the techniques for summarizing and describing the characteristics of neutrosophic numerical data. Since neutrosophic numerical data contain indeterminacy, *neutrosophic line plots*, and *neutrosophic histograms* are plotted in 3D space, rather than 2D space as in classical statistics. The third dimension, in addition to the Cartesian XOY system, is that of indeterminacy (I). From unclear graphical data, we can extract (unclear) neutrosophic information.
Neutrosophic data are data containing some indeterminacy. In a similar way to classical statistics, it can be classified as:
- *Discrete neutrosophic data*, if the values are isolated points; for example $6 + I_1$, where $I_1 \in [0,1]$,7, $26 + I_2$, where $I_2 \in [3,5]$;
- and *Continuous neutrosophic data*, if the values form one or more intervals, for example: [0, 0.8] or [0.1, 1.0] (i.e., not sure which).
Other classification:
- *Quantitative* (*numerical*) *neutrosophic data*;
For example a number in the interval [2, 5] (we don't know exactly), or; 47, 52, 67, or 69 (we don't know exactly);
- and *Qualitative* (*categorical*) *neutrosophic data*; for example: blue or red (we don't know exactly), white, black or green or yellow (we don't know exactly). Also, we can have:
- *Univariate neutrosophic data*, that is, neutrosophic data consisting of observations on a single neutrosophic attribute;
- and *Multivariate neutrosophic data*, that is neutrosophic data consisting of observations on two or more attributes. In particular cases, we mention bivariate neutrosophic data and trivariate neutrosophic data.

A neutrosophic sample is a chosen subset of a population. A subset that contains some indeterminacy: either concerning several of its individuals (who may not belong to the population we are studying or may only partially belong to it) or for the subset as a whole.

While classical samples provide precise information, neutrosophic samples provide vague or incomplete information. By abuse of language, it can be said that any sample is a neutrosophic sample since it can be considered that its indeterminacy is equal to zero.

Neutrosophic survey results are survey results containing some indeterminacy. A *neutrosophic population* is a population not well determined at the membership level (i.e., it is not sure whether some individuals do or do not belong to the population). For example, as in the neutrosophic set, a generic element x belongs to the neutrosophic population M as follows, $x(t, i, f) \in M$ which means: x is *t%* in the population M, *f%* of x is not in the population M, while *i%* membership of x in M is indeterminate (unknown, unclear, neutral: neither in the population nor outside).

3. Study of career preferences by gender at the Universidad Peruana Los Andes

For the study, all students who graduated from the Universidad Peruana Los Andes during the years 2021-2022 were taken into account. The total number of professionals trained was 4,691 in that period. The number of careers studied at the university is 19, each of them is classified within groups of career types, let us observe Table 1.

Table 1: Classification of the majors studied at the Universidad Peruana Los Andes

Group classification	**Careers studied**
Administrative and Accounting Sciences (I)	Administration and Systems Accounting and Finance

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Health Sciences (II)	Nursing Pharmacy and Biochemistry Human medicine Veterinary and Agricultural Medicine Human Nutrition Obstetrics Odontology Psychology Medical technology
Law and Political Sciences (III)	Law
Engineering Sciences (IV)	Architecture Civil engineering Environmental and Development engineering Computer and systems engineering Industrial engineering
Pedagogical Sciences (V)	Initial education Primary education

Additionally, each student was classified according to their permanence at this university using a neutrosophic number, according to the following criteria.

1. Those students who completed all their years of study at this university, in person and uninterruptedly, were associated with the number 1 or what is the same $1 + 0 \cdot I$.

2. Those students who completed the degree in one of the following ways were assigned the neutrosophic number $0.8 + 0.2 \cdot I$:

- Semi-person every year,
- They spent all the years in person, but the minority of years was spent at another university.

3. Those students who completed the degree in one of the following ways were assigned the neutrosophic number $0.6 + 0.4 \cdot I$:

- Distance learning courses at the university throughout the entire degree.
- Semi-in-person course most of the years of the degree and the rest were spent at another university.

4. The rest of the students who did not satisfy any of the previous cases were assigned the neutrosophic number $0.4 + 0.6 \cdot I$.

We establish $I = [0, 1]$. Note that although we deal with indeterminacy, the crisp case is taken into account when considering 1 in I.

According to the number assigned to each student, their gender, and the type of career shown in Table 1, the following contingency table was designed that contains neutrosophic numbers instead of crisp numbers.

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Table 2: Contingency table of graduates studied according to Career Type vs. Gender. Each career is represented by it roman number assigned in Table 1.

		Gender		
		Male	**Female**	**Total**
Career Type	**I**	$276 + 123 \cdot I$	$584 + 386 \cdot I$	$860 + 509 \cdot I$
	II	381	957	1338
	III	$210 + 94 \cdot I$	$180 + 219 \cdot I$	$390 + 313 \cdot I$
	IV	$385 + 411 \cdot I$	$169 + 156 \cdot I$	$554 + 567 \cdot I$
	V	7	153	160
	Total	$1259 + 628 \cdot I$	$2043 + 761 \cdot I$	$3302 + 1389 \cdot I$

The subjects on classical contingency table and chi-square test can be read in [17, 18]. To process the data we applied the neutrosophic chi-square test method of independence. This test consists of the following [6]:

Step 1. The null neutrosophic hypothesis is declared H_{0N} such that both variables are independent versus the alternative neutrosophic hypothesis H_{1N} such that both variables are dependent.

Step 2. The level of significance is specified as α.

Step 3. The neutrosophic values of the expected frequency are calculated using Equation 2:

$$\chi_N^2 = (O_N - E_N)^2 / E_N \qquad (2).$$

Step 4. The critical value of the contingency table χ_c^2 is selected with a degree of freedom $(r-1) \times (c-1)$ with the significance level α.

Step 5. H_{0N} is rejected if χ_N^2 is larger than the critical value. This means that the lower value of χ_N^2 is greater than χ_c^2 or χ_c^2 is between lower and upper values. Otherwise, it is not rejected H_{0N}.

When H_{0N} is true, the expected values of the hypothesis are that the number of men and women for each type of career is the same. That is, for type I careers, the number of men and women must be 684.5. For type II careers, the number is 669, it is 351.5 for type III majors, it is 560.5 for type IV majors, and it is 80 for type V majors.

The statistic of Equation 2 yields the result $\chi_N^2 = [1531.8, 3154.4]$. On the other hand, the critical value of χ_c^2 with 4 degrees of freedom is 9.49, since $(r-1) \times (c-1) = (5-1) \times (2-1) = 4$. So $9.49 < [1531.8, 3154.4]$ and therefore H_{0N} is rejected. This result is indicates that there is a dependency between the selection of the university major and the student's gender.

The careers where there is a greater male proportion are engineering and there is more or less parity in law career. The rest of the careers show a tendency to be chosen by women. This corresponds to gender stereotypes.

4. Conclusion

Gender parity can also be affected in higher education by the stereotypes that exist about what type of career to study. In the popular unconscious, there are preconceived ideas that some careers are for men and others for women. The objective of this paper was to test the proportion imbalance that exists in the selection of careers according to the sex of the person at the Universidad Peruana Los Andes. For this, we have data from 4,691 graduates of this university during the years 2021-2022. Apart from this, we wanted to take into account the indeterminacy of students belonging to the university, since not all are equally involved according to Smarandache's theory on Neutrosophic Social Structures. The data collected in the form of Neutrosophic numbers were processed with the Neutrosophic Chi-

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square method. The result confirmed that the "men's careers" are engineering, while legal sciences present a certain parity. The rest, such as biological, health and pedagogical sciences, among others, are dominated by women. This was confirmed by the test results. In future work we will compare these results with similar ones in other Peruvian universities. This will allow us to confirm or not whether this is a problem that exists throughout all the country.

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