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Women vs Men: Who performs better on Energy Literacy?

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ABSTRACT

Energy literacy is seen as one of the most powerful tools, available to ordinary people, to contribute to a more sustainable world. Since women tend to be considered the main caregivers, due to their maternal instinct, being generally more attentive, more altruistic, and more concerned with the future of their children, are women more involved in the transition to a more sustainable future? To answer this question, we seek to assess the literacy levels of Portuguese university members and explore the differences between men and women. Using the Heteroskedastic Ordered Probit, we found that women tend to have lower levels of knowledge about energy, but a more positive and sustainable attitude and behavior.

Keywords

Attitude;
Behavior;
Energy Literacy;
Knowledge;
Portuguese university members.

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1. Introduction

The climate changes that have been registered over the last few years make it increasingly urgent to change from an energy matrix based on fossil fuels to one focused on renewable energies. This energy transition implies not only substantial changes in technology and policies but also in the behavior of each one. Indeed, citizens' preferences, choices, and behaviors directly influence energy demand and shape the acceptance and effectiveness of technologies, strategies, and policies [1]. Defined by the US Department of Energy [2] as an understanding of the nature and role of energy in the world and our lives, and the ability to apply this understanding to answer questions and solve problems, energy literacy presents itself as an essential tool to this energy transition.

According to the literature review carried out (see section 2) an individual's energy literacy level is measured by their knowledge of energy-related issues, their ability to perform financial calculations (needed to understand the trade-off between price and efficiency), and their energy-related attitudes and behaviors. In general, knowledge about energy and financial knowledge are acquired at school, while attitude and behavior depend on awareness, willingness to change, and habits that are already ingrained. Thus, given the history, culture, and innate characteristics of men and women, there may be significant differences in their knowledge, attitude, and behavior.

Starting with education, we found that until a few years ago women hardly took a higher education course (their society role was to take care of the house, husband, and children), and it was men who had to study to have a better job and be the breadwinner of the house, nowadays, fortunately, women's are the majority in our universities [3]. Still, they have to give proofs, every day, of their dedication, competence, and merit, to be recognized. We have also acknowledged a gradual demystification concerning certain areas of education. Mathematics, engineering, management, communication, and information technologies, among others, are now chosen by both sexes, even persisting the trend towards masculinization of these areas [4]. The stereotypes defined by society often remove women from positions of leadership or of greater responsibility. In the same vein, they place an expectation on women, e.g.,

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that they are obligatorily and naturally more attentive, collaborative, and altruistic, without this type of attitude deserving recognition. By opposition, men are often rewarded for such attitudes [5].

Concerning sustainability, energy consumption, and involvement in the energy transition, there are also significant differences between men and women. Women are more sustainable consumers [6], as they value more eco-labeled products and green shopping, and are also more willing to change their energy-related behavior in favor of more sustainable options [7]. In the same vein, the study of Räty and Carlsson-Kanyama [8], applied to four European countries (Germany, Greece, Norway, and Sweden) reveals that, in general, men who live alone consume more energy than women who live in the same situation (mainly in transport and eating outside the home). However, it is men who fill most positions with the power to influence the energy transition, both in the corporate sector as well as in the public energy sector and civil society initiatives [9].

So, who will achieve the best results in energy literacy: men or women? Answering this question is the main objective of this paper. Although gender is frequently a significant item considered by environmental education studies [10], to the best of our knowledge, no study in Portugal analyses the differences between the levels of energy literacy of men and women. Literature shows some gender disparities, mainly in knowledge and attitude, with women showing lower levels of knowledge and more positive attitudes when compared to men. Looking at gender differences becomes relevant to evidence, validate and confirm, or not, these disparities and try to adequate the environment and climate change policies according to this information, to obtain better results. In reality, climate change and environmental policies affect people differently depending on various factors like gender, age, education, income, ethnicity, and religion.

Recently, Qarnain et al. [11] explore which factors cause social inequality and injustice finding the top three to be the limited participation of women in environmental campaigns, variations in building energy regulations worldwide, and ethnic/racial discrimination regarding environmental safety. Dorji et al. [12] investigated the gender differences in learning and energy-saving awareness through digital games finding that playing these games can decrease the gender differences. Lee et al. [13] found that female students displayed superior knowledge and affection regarding energy saving and carbon emissions reduction. More recently, Arachchi and Managi [14] analyze how gender differences affect the knowledge and importance of energy sustainability using a sample of 37 countries. In most of these countries, results support the findings that males have superior knowledge about energy sustainability than females. However, females are more concerned with energy sustainability importance. For Swiss households, men are found to be more likely than women to choose nuclear or hydroelectric options, as opposed to solar [15]. Concerning energy literacy studies applied to Portugal, Reis et al. [16] explore the issue but not considering gender differences.

Considering that a large part of the existing literature studies the energy literacy levels of students, we chose to study this segment of the population as well. We apply our study to university students because of three factors: some of them are having their first experience to live alone and to be responsible for the payment of electricity expenses; as university students, they have a higher level of education; and they represent the future adults or adults. However, we also included university professors and technicians to be able to consider the perspective of someone that generally has already its own home. Thus, using a sample of Portuguese university members (students, teachers, and technicians), we aim to measure the knowledge, attitude, and behavior related to energy and the energy literacy levels of men and women. As well, we test and verify if there exists evidence of significant differences, trying to measure these differences. Additionally, we provide some policy recommendations for the improvement of energy literacy levels, focusing on the proven gender differences.

2. Literature Review

Although there are several definitions of energy literacy, the most used in the literature seems to be the one provided by DeWaters and Powers [17]. These authors refer that energy literacy is divided into three main components: knowledge, attitude, and behavior. Knowledge assesses what a person knows about energy, attitude assesses personal beliefs and concerns related to energy and the willingness to adopt saving behaviors. Finally, behavior seeks to verify what the person does in their daily lives, trying to mirror the actions, even the most routine ones, related to energy. However, more recently, Blasch et al. [18], Kumar [19], and Filippini et al. [20] warned about the importance of energy-related financial literacy, that is, the ability to perform calculations that allows to correctly understand the trade-off between price and efficiency. In truth, financial literacy seems to

have a positive and significant impact on energy literacy as demonstrated by Martins et al. [21].

In the last fifteen years, the literature reveals low levels of energy literacy in New York [17], due to low levels of energy knowledge and behavior, and in Denmark [22] and Poland [23], mainly due to low levels of knowledge about energy costs. In truth, in Italy, the Netherlands, and Switzerland, most people do not know the average price of 1kWh of electricity [18]. There is also evidence of strong dichotomies between attitude and behavior in Taiwan, with attitude being significantly more positive [13,24], showing not only the difference between what people say and what people do but also the fact that most of the behaviors related to energy are often almost automatic and little thought, being defined by strong habits difficult to change. In Portugal, the reality seems to be the same, considering the results of the study recently published by the Energy Services Regulatory Authority (ERSE)[25], showing the lack of information of the majority of consumers about the existing producers, distributors, and providers of electricity, and about the existing simulators of electricity price. The same study shows that only 42.2% of private users and 54.8% of business users know what items are presented in electricity bills. Consumer involvement is also explored by Krog et al. [26] and their necessary involvement in energy transition issues was identified.

The literature mentions several factors capable of influencing energy literacy levels, namely age [19], frequency of energy-related courses [13,22], is responsible for the payment of electricity [27,28], parents' influence, and recommendations [29], risk aversion [30], and concern with free-riding [19]. Another important factor is gender. Much of the previous literature reports that women have less knowledge about energy and financial related issues [18–20,31,32]. Looking at the statistics related to the areas of training for men and women, we find that courses related to mathematics and finance are still mostly attended by men [4]. However, another trend of the existing literature argues that women show a more positive attitude towards the need to save energy [6,8,33,34]. Zelezny et al. [35] also support this idea, suggesting that women are more receptive to sustainability.

3. Data and Methodology

To explore the differences between women and men concerning energy literacy and its dimensions, we use data from a questionnaire defined by Martins et al. [21] and applied it to Portuguese university members (technicians, teachers, and students) from several universities and polytechnic institutes of the country. The questionnaire has 31 closed questions to measure energy knowledge, which include questions about the units in which energy is measured, ways to produce energy, different types of energy, what is the correct temperature for heating/cooling and saving energy, etc., and 4 closed questions to assess financial knowledge, which includes questions about interest and inflation rates, and the trade-off between price and efficiency. Additionally, the questionnaire includes an open question to measure price awareness, 19 Likert scale questions to measure attitude, where we try to understand if people are concerned about the necessity of saving energy and change some behaviors, and finally, 11 Likert scale questions to measure behavior, where we try to check if people have the correct habits related to the consumption of energy. To determine the levels of energy and financial knowledge we assigned one point for each correct answer and zero points for each incorrect answer. To assess the energy price awareness, we ask the participants to indicate the average price of 1kWh of electricity. According to PORDATA information for 2019, the correct value was 0.2150 Euros, so we considered the answers between 0.15 and 0.27 Euros correct and assign them a point. For the questions related to attitude and behavior, we assign points between 1 and 5, with 1 corresponding to a negative attitude or an incorrect behavior and 5 corresponding to a positive attitude or correct behavior. Following the works of Barrow and Morrisey [36], Armstrong and Impara [37], and DeWaters and Powers [17], we summed the points obtained in each question and obtained the total points for each dimension. Then we add up the totals obtained in each dimension to obtain the energy literacy level. The maximum energy literacy level it could be achieved is 186 points. Thus, we define that literacy levels between 0 and 70 (0-38%) were considered low, from 70 to 140 (38-75%) were considered moderate, from 140 to 160 (75-86%) were considered good and levels from 160 to 186 (86-100%) were very good.

Appling this questionnaire between January and October of 2020, we were able to collect 428 valid answers. Most of the participants are women (68.22%), just over half live in their own home (58.88%) and approximately half are responsible for the payment of electricity expenses (50.70%).

The proposed methodology to study gender differences is, comporting with other studies undertaken by researchers modeling individual-level survey responses, following Filippini et al. [20]. However, [20] uses the simple

ordered probit model, while in the present article we apply the heteroskedastic ordered probit model considering the nature of our dependent variable being levels of knowledge, attitude, and behavior, evidenced by the respondent's answer. The heteroskedastic ordered probit model generalizes the ordered probit allowing the variance to be modeled as a function of independent variables and to differ between subjects or groups in the population.

Let y_i denote an observable variable based on responses to literacy levels. Therefore, y_i^* will represent an unobservable variable capturing the literacy level of the ith individual, where responses refer to the percentage of correct answers. The literacy outcome can be expressed as a function of a vector of explanatory variables (x_i) using equation (1) and β being a vector of unknown parameters.

$$y_i^* = x_i'\beta + \varepsilon_i \text{ where } \varepsilon_i \sim N(0,1) \quad (1)$$

We assume that y_i^* is related to the observable variable y_i as follows (the ordinal values of the literacy score) and μ_j's are the threshold parameters. These are represented by

$$[\textit{'low literacy levels'}] \textit{ if } -\infty < y_i^* < \mu_1$$

$$[\textit{'moderate literacy levels'}] \textit{ if } \mu_1 \le y_i^* < \mu_2$$

$$[\textit{'good literacy levels'}] \textit{ if } \mu_2 \le y_i^* < \mu_3$$

$$\text{and } [\textit{'very good literacy levels'}] \textit{ if } y_i^* \ge \mu_3.$$

For more details about the heteroskedastic ordered probit model, we refer to Green and Hensher [38].

The assumption of threshold homogeneity ($\sigma^2 = 1$) is crucial to specify the ordered probit model. However, the ordered probit model estimates are known to be subject to bias and inconsistency in the presence of heteroscedasticity. Provided we are interested in determining the separate impacts of covariates of the mean and variance of the latent dependent variable we have incorporated a general form of heteroscedasticity (equation (2)).

$$\sigma_i = \exp(w_i\delta) \quad (2)$$

Being w_i a matrix of variables found to be the source for the residual dispersion and δ a vector of unknown parameters. We assume this model considering it provides a fairly simple structure, that the simple non-linear variance form has fewer convergence computational problems in maximum likelihood estimations, and ensuring the estimated variance is positive.

We estimated the model separately for each score that we were interested in, namely, energy knowledge, energy attitude, energy behavior, and energy literacy. Concerning the energy knowledge of individuals, we computed both the homoskedastic and heteroskedastic ordered probit models. To model the variance, we chose the gender variable, which proved to be adequate and significant in explaining the variance of the components of attitude, behavior, and also of energy literacy. The estimated model for knowledge does not seem to present heteroscedasticity problems, considering the p-value of the χ^2 statistic (0.5613), the reason why we present also the result of the ordered probit model (Table 2).

4. Results

To begin our analysis, we decided to test whether the results obtained in terms of knowledge, attitude, behavior, and energy literacy levels are significantly different between men and women. The results obtained are described in table 1 Overall, the levels of energy and

Table 1: Differences on energy literacy scores between men and women.

	Mean	Std. Err.	t (H_0: diff=0)	p-value
Energy Knowledge				
Men	0.6985	0.01085		
Women	0.6363	0.0082		
Difference	0.0622	0.0141	4.4238	0.0000
Price Awareness				
Men	0.4191	0.0425		
Women	0.2568	0.0256		
Difference	0.1623	0.0474	3.4226	0.0007
Financial Knowledge				
Men	0.6801	0.0247		
Women	0.5163	0.0182		
Difference	0.1639	0.0315	5.1958	0.0000
Attitude				
Men	0.7991	0.0071		
Women	0.8185	0.0039		
Difference	–0.0195	0.0075	–2.6024	0.0096
Behavior				
Men	0.7820	0.0085		
Women	0.8038	0.0045		
Difference	–0.0218	0.0088	–2.4801	0.0135
Energy Literacy				
Men	0.7727	0.0063		
Women	0.7743	0.0036		
Difference	–0.0016	0.0068	–0.2420	0.8089

financial knowledge seem to be reasonable, which would be expected considering that our sample is constituted by university members. The behavior seems to be good, which can be explained not only by the reasonable levels of knowledge and by the good levels of attitude, but also by the high prices of electricity. The biggest differences between women and men are verified in the levels of price awareness and financial knowledge, with men obtaining the best results. Men also get the best results in energy knowledge, although the difference is smaller. Concerning attitude and behavior, it is women who seem to demonstrate a more positive and proactive attitude towards the need to save energy, more easily implementing sustainable habits in their daily routines. This can be explained by the high percentage of women of our sample that study Natural and Environmental Sciences (10.27%) comparing with the percentage of men that study this theme (2.94%). These results are also confirmed by the study of Wall et al. [3], applied to Portugal, that shows that men prefer fields like engineering, manufacturing, and construction industries, and services (personal, transport, security, and environmental protection) at the expense of education, health, social welfare, social science, commerce, and law. These last scientific fields are more prone to be chosen by women as their field of education. Finally, in the levels of energy literacy, the difference between men and women seems to be diluted, not being statistically significant, however, women show slightly higher results. The level of energy literacy is good, however, there is still space for improvement, mainly in energy and financial knowledge that are moderate, and in energy price awareness that is moderate for men, and low for women. Lack of energy and financial knowledge and low energy price awareness can compromise the energy transition, so it is necessary to bet on energy and financial training. Knowing that women have the less financial knowledge and have more difficulty in saying correctly the electricity price can help national authorities to define more targeted policies and measures to improve this reality.

Then we estimate the influence of some factors on the different components of energy literacy and also on energy literacy, using the Heteroskedastic Ordered Probit model (see Table 2). Considering the results, we may say that females possess lower energy knowledge despite demonstrating stronger attitudes, behavior, and energy literacy levels than males (positive coefficient, on average, in Table 2). Concerning gender differences, our results contradict those of Lee et al. [13] but favor those of Arachchi and Managi [14]. Energy literacy scores include the three dimensions of knowledge, attitude, and behavior, which justify the results also evidenced previously in Table 1. Also, Qarnain et al. [11] reveal the limited participation of women in environmental campaigns causing social inequalities and injustice. Thus, education and learning are valuable suggestions to surpass it [12].

Regarding knowledge, the results show that women know less about energy-related topics than men. The level of education is not significant in determining the level of knowledge; however, the background seems to play a very important role. Participants who have backgrounds in exact sciences and engineering and on natural and environmental sciences have significantly higher levels of energy knowledge than participants who studied health and life sciences. In turn, participants who have backgrounds in social and human sciences and others have significantly lower levels of energy knowledge than those who have studied health and life sciences. The fact of living in a house or a rented house does not seem to have any influence on energy knowledge. Contrary to our previous expectations, the responsibility for paying electricity bills seems to have a negative influence on energy knowledge levels, which may be related to the fact that the participants who are responsible for paying the electricity bill are mostly the adults or seniors, that probably have not been as aware for the importance of these themes as were the younger generations. Financial knowledge and concern about the price of electricity seem to positively and significantly influence energy knowledge.

We also find that older respondents, on average, have higher levels of energy knowledge although the effect of age on attitude, behavior, and energy literacy is insignificant. More discussion of age effects on energy literacy may be found in Martins et al. [39] and Martins et al. [40] in the Portuguese context. Regarding knowledge, our results contradict those of Filippini et al. [20]. Thus, we favor the opinion that older respondents faring better on energy knowledge suggest that improvements in the quality of education at the present is necessary to increase energy literacy over time. This may as well impede the necessary knowledge to pursue the requirements of the necessary energy transition. Krog et al. [26] defend that the building's heat demand has to be reduced and consumer behavior has to be adapted for the energy transition, which can only be done through higher energy knowledge.

Table 2 - Heteroskedastic Ordered Probit estimations.

	Energy Knowledge		Attitude	Behavior	Energy Literacy
	Het. Ord. Probit	**Ord. Probit**	**Het. Ord. Probit**	**Het. Ord. Probit**	**Het. Ord. Probit**
Gender	–0.2744**	–0.2664**	0.3142***	0.3331***	0.2297**
	(0.1148)	(0.1120)	(0.1070)	(0.1064)	(0.1065)
Age	0.0129**	0.0125**	–0.0018	0.0014	0.0050
	(0.0061)	(0.0059)	(0.0054)	(0.0053)	(0.0054)
Education Level	–0.0570	–0.0571	0.0149	0.0475	–0.0029
	(0.0555)	(0.0540)	(0.0479)	(0.0467)	(0.0485)
Background on Exact sciences and engineering	0.4786***	0.4611***	–0.1539	–0.2285	–0.0026
	(0.1769)	(0.1691)	(0.1492)	(0.1457)	(0.1498)
Background on Environmental and Natural sciences	0.4182*	0.4044*	0.1624	–0.0889	0.2348
	(0.2334)	(0.2239)	(0.1933)	(0.1878)	(0.1955)
Background on Social Sciences and Humanities	–0.7500***	–0.7358***	–0.0837	–0.0069	–0.4301***
	(0.1887)	(0.1816)	(0.1617)	(0.1580)	(0.1620)
Background on Others	–0.4562*	–0.4499*	–0.1035	0.2432	–0.1861
	(0.2428)	(0.2355)	(0.2091)	(0.2028)	(0.2107)
Home	–0.0191	–0.0132	0.0444	0.0482	0.0521
	(0.1146)	(0.1106)	(0.0971)	(0.0943)	(0.0985)
Responsibility	–0.2634**	–0.2504**	0.0285	–0.0447	–0.1128
	(0.1280)	(0.1221)	(0.1074)	(0.1045)	(0.1085)
Energy Knowledge			1.3185***	1.4859***	
			(0.3838)	(0.3775)	
Financial Knowledge	1.3230***	1.2859***	0.0940	0.0444	1.0108***
	(0.1911)	(0.1748)	(0.1600)	(0.1561)	(0.1673)
Price awareness	0.3728***	0.3588***	0.1223	0.1810*	0.3967***
	(0.1182)	(0.1125)	(0.1002)	(0.0976)	(0.1029)
LR chi2	178.14	177.88	34.18	36.57	93.70
P-value	0.0000	0.0000	0.0006	0.0003	0.0000
Pseudo R2		0.0745			
lnsigma					
Gender	0.0444		–0.1728**	–0.2116***	–0.1548**
	(0.1182)		(0.0763)	(0.0799)	(0.0762)
LR chi2	0.34		13.27	7.28	4.26
P-value	0.5613		0.0003	0.0070	0.0391
Number of obs.	428	428	428	428	428

Note: Standard errors are in parenthesis; *, **, *** refer, respectively, to the 10%, 5% and 1% significance levels.

As well, our results also highlight the importance of energy knowledge on the attitude and behavior of individuals, as financial knowledge is important for energy knowledge and literacy [20]. Thus, only improvements in energy knowledge, through adequate educational levels, could reduce gender disparities and ensure the future energy transition [26]. Looking at price awareness, we note that on average, respondents with higher sensitivity to price changes are those with higher levels of energy knowledge, present greater behavior and possess energy literacy levels, which is as well consistent with the need for energy-educational issues and highlights the need for consumer behavior adaptation needs [26] to follow the correct path for the desired energy transition, despite the finding presented in Table 2 that responsibility for the energy bill, by the household, negatively affects energy knowledge.

Looking now at the results obtained for the attitude, we find that its major determinants are gender, with women showing a more positive attitude, and energy knowledge, showing a positive ad significant impact. Concerning behavior, women also seem to be in advan-

tage, showing more appropriate behaviors. Energy knowledge and electricity price awareness also seem to play a positive and significant role. Finally, looking at the estimation for Energy Literacy, we see a positive and significant influence of gender, financial knowledge, and electricity price awareness. Having a background in social and human sciences seems to be synonymous with a lower level of energy literacy when compared to the level of energy literacy of participants who have backgrounds in health and life sciences.

We surveyed university members including students, professors, and other employees, making the sample a general one for university members, even if a small one. The Portuguese society assumes a different behavior regarding heating in winter since there are no such coldest winters as in some other EU countries [26,41], and consequently, people do not need to heat houses as much. Moreover, the Portuguese population faces one of the heaviest electricity burdens in the EU [42], so they have a particular interest in adopting energy-saving behaviors. Therefore, results can be generalized to other citizen samples in Portugal and faced with differences from other countries facing opposite situations or compared with those EU countries in similar conditions. This work is left for a broader article collecting data from a broader EU sample and comparing differences and similarities among respondents' levels of energy knowledge, attitude, behavior, and energy literacy, which in our opinion will provide more insightful and interesting results.

5. Conclusions

Since energy literacy is a powerful tool, capable to sensitize citizens to adopt sustainable energy consumption habits, and considering the important role of citizens in the energy transition, we think that it will be useful and necessary to assess the levels of energy literacy among Portuguese. This assessment allows us to understand in which dimensions of energy literacy it is necessary to act, and helps us to understand which policies should be adopted to improve energy literacy levels.

Our results show that Portuguese university members have good levels of energy literacy and that there are no significant differences between the energy literacy levels of women and men. However, we verify significant differences in the levels of energy price awareness and financial knowledge, with men obtaining the best results. The fields of study predominantly chosen by women may determine their low financial knowledge and energy price awareness.

The results also suggest that, although women show less knowledge related to energy and finance, they seem to demonstrate better attitudes and behavior. Consequently, women seem to have slightly better levels of energy literacy.

The field of education seems to have an important role in knowledge and energy literacy levels, with participants with backgrounds in social and human sciences presenting significantly lower levels than those who have studied health and life sciences. Financial knowledge and concern about the price of electricity seem to positively and significantly influence energy knowledge.

Despite the good levels of energy literacy observed, our study also demonstrates there is still space for improvement, mainly in energy and financial knowledge that are moderate, and in energy price awareness that is low for women, and moderate for men. To improve these low levels of energy and financial knowledge we suggest providing energy and energy-related financial lessons to students, using practical activities that bring them closer to everyday situations, at all levels of education and independently of the field or area of study. Girls, in particular, should be alerted to the importance of financial literacy and should be encouraged to study areas such as mathematics, finance, engineering, among others. To improve the energy literacy of adults free specific energy and financial literacy training should be developed, and television programs that address these issues, giving correct information, and teaching them how to make better choices when purchasing electrical equipment, for example.

In further studies, it is suggested to measure the gender differences in energy literacy among elementary students, or if possible of households to have a better perception of the energy literacy levels in Portugal. Additionally, it is also suggested to study the influence of other factors such as income and concern about free-riding on energy literacy.

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