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MODELLING UNIVERSITY STUDENTS PERCEPTION ON DEMAND RESPONSE PROGRAMS

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ABSTRACT

The demand response (DR) programs intend to influence the consumers (household, commercial and industry) behaviour, to promote their active participation in the energy market and to improve their load pattern. This research work addresses the issue of public awareness and acceptance for DR programs. The study focused on a methodology supported on survey of an academic sample of students from one university in Portugal. From the collected information a statistical model based on linear regression was proposed. This study suggests that female students are more willing than male students to defer their electricity consumption. Other factors such as knowledge on time of usage (TOU) tariffs, concerns about reduction of imported energy and the acceptance of the automatic control of the heating or cooling system could have a positive effect on the willingness to defer electricity use. The conclusion of this paper presents then important insights for encouraging the students to engage in DR programs. Moreover, and in spite of the homogenous characteristics and reduced size of the sample, the results allowed to demonstrate the relevance of the study and to propose directions for its extension for a larger population.

INTRODUCTION

Today the energy sector is recognized as one of the greatest threats to climate change, this is, however, to be expected, since 2014, the energy sector was responsible for 42% of total Carbon Dioxide (CO2) in member countries of the Organization for Economic Co-operation and Development (OECD) (IEA, 2017). Thus, the developed countries are being motivated to reduce their energy consumption in order to reduce their energy footprint while fostering more efficient energy production systems and consumption technological solutions. To tackle this, the adoption of more efficient behaviours by end-users must also be considered and the adoption of Demand Response (DR) programs is emerging, which aim to ensure a more efficient use of electric energy and thus bringing economic and environmental benefits.

The DR programs present as main objective the reduction of the electricity peak through shavings and valley-fillings, which should allow to reduce electricity cost and improve the power grid performance (Riesz et al. 2016). Namely, the DR programs intends to encourage final consumption consumers to be active and participate in the energy market since the end-user should adjust their electricity consumption according to electricity price, i.e., the und-user should shift their electricity consumption away from peak periods, when electricity price is higher (Goulden et al. 2014).

In the literature, several possible types of DR programs are considered, based on the Federal Energy Regulatory Commission (FERC) the DR programs can be categorized in one if two ways: Price – based demand response programs (PBDRP), (b) Incentives – based demand response programs (IBDRP) (Figure 1).

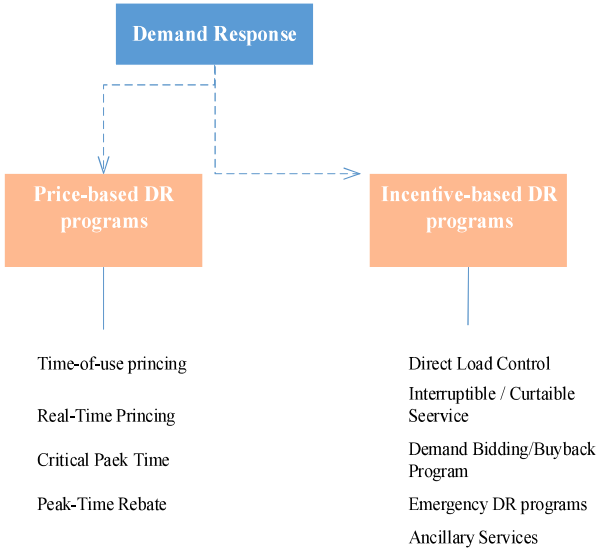

Figure 1: Classification of DR programs

The PBDRP, assume that the electricity price is not constant: during the peak period the prices are higher, and during the peak- off period the prices are lower. If the consumers respond to the price structure, shifting or reducing their consumption, they will be compensated for

the reduction on their electricity bill. IBDRP, are established between the operator grid and the consumers. The consumers can receive tariff discount by load reduction, but if they do not comply, they will be penalized (Nederland et al. 2013) (Weck et al. 2017).

The optimization of consumption periods and other flexibility options should also help importing countries to reduce dependence on fossil fuels, which will have repercussions on cost and overall economic performance of the country. To this end, apart from rationalizing energy consumption and making it more efficient, the maximization of the use of renewable sources should also be considered with the overall goal of reducing importations and reducing climate impact. For this, measures must also be drawn on the demand side, so end-users play a crucial role in adapting their consumption according to the availability on renewable energy sources (Afonso et al. 2017).

The study of residential electricity consumption has generated significant interest in the literature. Many authors have been investigating the domestic energy use, using primary data collection (Li et al. 2017); (Du et al. 2017); (Lopes et al. 2016);.(Spence et al. 2015) and (Zhang and Lin 2018). This methodology has a relevant role since it allows us to evaluate the importance of the characteristics of the dwelling and household behaviour to related residential energy use and sociodemographic characteristics. Namely, the using of primary data collection makes it possible to assess household behaviour more closely, that is an important tool for policymakers to draw intervention policies (Jaffar et al. 2018).

According to (Zhang and Lin 2018) and (Liao and Cao 2018), the sociodemographic characteristics play a crucial role in improving the DR programs. On the other hand (Srivastava et al. 2018) found that socioeconomic variables such as income and education are not significant to DR success. However, the authors concluded that the implementation of DR programs seems to be correlated with the extension of urbanization, in urban areas, where population density is greater, and consumers tend to be more aware about environmental concerns, renewable energy targets and economic growth rates. Urban areas usually use more electricity than rural areas (Du et al. 2017), so to deploy more effective and quicker DR programs urban areas and in particular the faster-growing cities, are to be considered. These areas not only seem to be more receptive to these programs but also are more willing to carry out extensive investment required, increasing the success of the programs.

Another factor to have in mind for the success of DR programs is the heterogeneity of the household (Cowen and Gatersleben 2017), in order to offer different electricity tariffs. These include for example Time- of-Use (TOU) or Critical Peak Time (CPT), where the electricity prices change according to peak or peak-off periods, and the end-users decide can program their electricity use daily routine accordingly.

Furthermore, the promotion of technological advancement with the view to reduce the electricity consumption, such as smart meters and in-home displays that provide real time of electricity usage are required. These devices allow for the effective implementation of the DR program and increase the consumer awareness, as there is a clear relationship between price and electricity consumption time (Morrissey et al. 2018).

Studies which use survey approach can provide more detailed information about the household behaviour and dwellings. The disadvantages of primary data collection are that there is no way to evaluate the veracity of the interviewee's answers and this can influence the results obtained.

In this study we present a regression model supported on survey of an academic sample of students from one university in Portugal using a stated preference technique.

The paper has four research questions, actually: (a) What are the sociodemographic characteristic that influence the respondents to defer their electricity consumption; (b) How can the knowledge and dynamism towards energy sector of the respondents encourage the end-users to defer their electricity use; (c) What are the motivational factors (environmental factors, reduce the imported energy, reduce the electricity bill and social effects) that influence the respondents do defer their electricity usage and (d) Are the respondents willing to be flexible on the electricity use. For the statistical analysis of the results a model based on Ordinal Least Squares (OLS) was proposed.

The paper is structured as follows: first, we present a short description of the survey and their response, secondly, the methodology is addressed, thirdly, the statistical analyses is presented, and the model is detailed. Lastly, conclusion and policy implications were considered.

SURVEY TO ACESS THE STUDENT OPINION

The survey aimed at studying the differences in public perception about electricity usage. The survey was conducted through Web-survey during May of 2018, which was implemented into the University of Minho. An overwhelming majority of the answers were collected from engineering students (80,8%, from engineering fields).

The questionnaire was divided into four sections, where the first section evaluates the sociodemographic characteristics of students. The second section is about knowledge and dynamism, in which we examine the knowledge of the students on the electricity tariffs asking them if they are familiar with terms TOU tariffs. The dynamism of their household was used as proxy by three factors, such as, the regular communication of the electricity consumption to electricity supplier, electricity supplier switching (in the last two years) and ownership of electricity monitoring device. The third section appraises the motivational factors to defer the electricity usage, in which the environmental factors, reduction of

energy importation, reduction of electricity bill and the following of acquaintances advice are considered. Finally, in the fourth section the willingness to defer the start of a given domestic appliance (e.g. washing and dryers machine) was measured, questioning the student about the value of their electricity bill, and their willingness to defer the use of their domestic appliances for 1-2 hours, 3-6 hours or for more than 6 hours. In order to facilitate the public's understanding absolutes values for potential cost savings were referred.
The possible answers were coded into STATA 15 (table 1). The answer "does not know/ does not answer" was coded as zero in order to avoid counting and not so as not interfere with the statistical tests.

Table 1: Variables encoded in STATA

Variable name	Code	Short description
AGE		Age of respondents
GENDER	0" male" and 1 "female"	Gender of the respondents
COURSE		The course enrolment that the respondents are attending
EDUCATION	1" under-graduation" 2" master"	Academic level of the respondents
STUDENTWORK	0"no";1" yes"	Student status of the respondents
HOUSEHOLD		Household size of the respondents
METER	0"no" 1" yes"	If the respondents provide the meter reading to their electricity supplier
SUPPLIER	0"no" 1" yes"	If the respondents switch their electricity supplier
TARIFFS	0"no" 1" yes"	If the respondents are familiar with TOUs tariff
SMARTMETER	0"no" 1" yes"	If the respondents have a monitoring device
WTD	0 "not are willing to defer the electricity usage "2 "tent to are willing to defer the electricity usage "3 "are willing to defer the electricity usage"	If the respondents are willingness to defer their electricity consumption
ENVIRONMENTAL	1 " totally agree" 2 "tend to disagree" 3 "tend to agree" 4 "totally agree" 0 " no answer"	If the respondents are willing to defer their electricity consumption for environmental factors
IMPORTS	1 " totally agree" 2 "tend to disagree" 3 "tend to agree" 4 "totally agree" 0 " no answer"	If the respondents are willing to defer their electricity consumption in order to reduce the energy imports
REDUCE_BILL	1 " totally agree" 2 "tend to disagree" 3 "tend to agree" 4 "totally agree" 0 " no answer"	If the respondents are willing to defer their electricity consumption in order to reduce the value of electricity bill
OPINION	1 " totally agree" 2 "tend to disagree" 3 "tend to agree" 4 "totally agree" 0 " no answer"	The respondents are willing to defer their electricity consumption if someone else recommend us
ELECTRICITYBILL	0" no answer" 1 "25€ or less" 2"26€- 55€" 3"56€-100€" 4"101€-150€" 5" more than 150€"	The value of the electricity bill that the respondents pay for month
AUTOMATIC_CONTROL	1 " totally agree" 2 "tend to disagree" 3 "tend to agree" 4 "totally agree" 0 " no answer"	The respondents are willingness to defer of the heating or cooling system

The main results of this survey suggest that the students are well familiar with TOUs tariffs, as more than 60% of the respondents answered that they are familiar with terms related to TOU tariffs ("bi-horário" e tri-horário" in Portuguese). Also, the respondents considered that environmental factors, reduction of cost and reduction of energy imported are crucial factors to motivate the students to defer the electricity usage. At the same time, a friend, neighbours, relatives and among others recommendation, while it was acknowledged, it does not play a significant role in their decision. Our results also demonstrate that the savings expectations can play an important role to encourage the consumer to be more flexible, i.e., the respondents are available to defer their electricity consumption. However, the respondents show some reluctance on deferring the use of their domestic equipment for more than six hours. Willingness to change energy behaviour based on some automatic device was reviewed, where a vast majority of respondents are available to set automatically their heating or cooling system temperature according to market tariffs. This reveals that young people with high academic level are highly susceptible to the use of new innovative technologies, representing an important market segment for future DR programs.
A detailed description of the survey and statistical testing can be found in Ferreira et al, (2018).

METHODOLOGY

This paper works up a survey of 125 students from University of Minho. The data used is small since the survey was conducted as a pilot project in order with the aims of a future research to apply this study to Portuguese citizens. We chose to work with a survey data, given that

it is an efficient procedure to collect data from several interviewed, within a short time and it is an efficient mean of collecting data on large scale.
To better understand what the motivational factors are, in which students defer their electricity usage and their willingness to accept automatic control of their heating or cooling system the students were asked about their agreement with some sentence, for each question, we provided five options for the students to choose, the 5-level Likert scale ranged from "totally disagree"; "tend to disagree"; "tend to agree"; "totally agree" and "does not know/ does not answer".
To test the reliability, or internal consistency, of the Likert -scale was carried out the Cronbach's Alpha test (table 2). Where the average value of this test is 0.7097, which shows us these variables pass test (Remarks et al. 2013).
The Variance Inflation Factor (VIF) was calculated to assess the presence of multicollinearity, and the means were 1,49 which revealed the nonexistence of multicollinearity.

Table 2: Results for Cronbach's Alpha test

Variables	Alpha	Sign	Obs
ENVIRONMENTAL	0.5468	+	125
IMPORTS	0.6038	+	125
REDUCE_BILL	0.6915	+	125
OPINION	0.6915	+	125
AUTOMATIC_CONTROL	0.7446	+	125
Average value of Alpha = 0.7097			

To evaluate the willingness of the student to defer electricity use an ordinal regression analysis was defined. The dependent variable is WTD, which is classified as ordinal. Stata software suite tools of survey data command is administered by the *svy* prefix command. We use the *svy* prefix with the *regress* command to model the association between sociodemographic variables; knowledge and dynamism; motivational factors for energy management; flexibility on electricity use and the willingness to defer their electricity consumption. The *svy* command takes into account the survey design characteristics.
When we perform a linear regression, that includes ordinary least squares and weighted least squares, in which are applied as a tool for exploring relationship, effects and might provide some answers to public policy questions. The assumptions of homoscedasticity, the normality and no auto-correlation are needed to validate the regression. Nevertheless, prefix *svy* was used, in which bases its inferences on the sample design (sampling weights, cluster sampling and stratification), i.e., it is robust to violations of those assumptions, in other words, we do not need to test these assumptions to validate the model. Thereafter following the estimated coefficient, our fitted model is:

$$WTD= \beta_0 + \beta_1 GENDER + \beta_2 METER + \beta_3 TARIFFS - \beta_4 SMARTMETER + \beta_5 IMPORTS + \beta_6 AUTOMATIC\_CONTROL$$

To check whether the model is correctly specified the link test (table 3) was carried out.

Table 3: Results for the link test

Variable dependent	P> t
WDT	
_hat	0.035
_hatsq	0.116
_cons	0.114
_hatsq= prediction square	

As the results indicate that the prediction square does not have explanatory power, the model is considered to be well specified.

RESULTS AND DISCUSSION

Having in mind the objectives of this study, an ordinal linear regression was conducted with prefix *svy* being used as a dependent variable: the willingness to defer electricity use.
According to the results that are disclosed in table 3, the sociodemographic variables do not play a crucial role on the acceptance of deferring the electricity consumption in which most of the variables were not statically significant. However, the gender, reveals that the gender could influence the willingness to defer electricity usage. In this study a large share ,72%, of the female students are more willing to defer their electricity use, while only 52% of the male students are willing to defer their electricity use. We can demonstrate that female students are more available to adopt the DR programs.
The knowledge of the respondents was measured through if the respondents are familiar with terms "bi-horário" and "tri-horário" in line with the statistical results the possibility to switch from flat-rate tariffs to TOUs tariffs, the knowledge was observed, contribute positively to the respondent's willingness to defer their electricity usage. This finding is in line with some studies carried out in other countries, such as, (Nicolson et al. 2017), (Jaffar et al. 2018) which also concluded that the knowledge of the possibility to switch for TOUs tariffs have a positive effect in order to encourage the residential consumers to adopt the DR programs.
In order to analyse how the dynamism, influenced the respondents to defer their electricity usage, it was found that those who state they regularly provide the meter reading to their electricity supplier tend to be more willing to participate in DR programs. As Weber et al. (2017) showed regularly communicating the electricity usage to electricity supplier tends to strength consumer awareness about their energy usage

Table 4: Results for to analysis the willingness to defer the electricity usage

Independent variables		OLS
Sociodemographic variables		
	AGE	0.016
	GENDER	0.192**
	COURSE	-0.012
	EDUCATION	0.0316
	STUDENTWORK	-0.099
	HOUSEHOLD	-0.0217
Knowledge and dynamism on electricity consumption	*METER*	0.1608**
	TARIFFS	0.167**
	SUPPLIER	-0.057
	SMARTMETER	-0.156*
Motivational factors for energy management	ENVIRONMENTAL	-0.0229
	IMPORTS	0.149***
	REDUCE_BILL	-0.003
	OPINION	.0033
Flexibility on electricity use	ELECTRICITYBILL	-0.005
	AUTOMATIC_CONTROL	.0051*
N		125
R^2		0.2942
F (16,109)		4.50***
Notes: OLS – Ordinary Least Squares; F-test: where the null hypothesis is of non-significance of the estimate parameters; ***, **, *, denote statistical significance at 1%, 5% and 10% levels, respectively.		

Namely, with the technological progress such as a smart meter it is expected that it has a positive effect on willingness to defer the electricity usage since this device can provide a more detailed information about electricity price, i.e., the consumer may decide to use electricity when price is lower. However our results suggest that the smart meter ownership has a negative relationship with the willingness to defer electricity usage, this fact could be explained by the end-user disliking the idea of energy supplier managing their energy consumption, and are concern about the privacy and security of the data (Ghani and Ahmad 2010; Sovacool et al. 2017).

The results show that those of show concerns about the reduction in dependence on imported energy tend to be more positive towards deferring their electricity. This shows that motivation towards DR programs can go much beyond financial ones, and young, well informed population can value social and national concerns as well.

Our results suggest that, accepting the automatic control for the heating or cooling system has a positive effect on the student's willingness to defer the electricity consumption. The automatic control for the heating or cooling system involves reducing the set point when the electricity price is higher since the heating and cooling system sector accounts for approximately 50% of overall EU final energy consumption (European Commission 2007). This analysis reveals that the monetary considerations could have an important role to the end-user deferring their electricity use, since the heating and cooling system have a huge impact on the electricity bill. This finding, related to a positive association between the acceptance to reduce the set point of the heating or cooling system and the willingness to defer electricity use were identified in other studies, such as (Grunewald and Diakonova 2018) and (Li et al. 2017).

CONCLUSIONS

This paper addressed the association between the independent variables (sociodemographic variables; knowledge and dynamism on electricity consumption; motivational factors for energy management and flexibility on electricity use) and the dependent variable willingness to defer electricity use. For this, an ordinal linear regression model was proposed to statistically analyse data from a survey with an academic sample of students from one university in Portugal

The proposed approach aimed to demonstrate if and how the respondents would consider to defer their electricity use and what factors have an impact on this willingness. To do this, an evaluation of the independent variables statistical significance in relation to the dependent variable was considered.

The statistical significance of the model coefficients is low, which derives from the rather homogenous characteristics and reduced size of the sample. However, the results allowed to demonstrate the relevance of the study and of the proposed model, which for a large population can be used as a tool to support decision making testing on the potential acceptance of different policies.

So, our results discovered that, female users tend to communicate more regularly the reading of the meter to the energy supplier. The knowledge on TOUs tariffs, concerns about imported energy and the acceptance of the automatic control have a positive effect in encouraging the student to accept a DR program which would imply deferring electricity use over time. On the contrary, having a smart meter (a device that enables to see the electricity price in real time) has a negative effect on the willingness to participate. These somehow puzzling results can reveal a true concern with energy use and management but some mistrust on the system that may be jeopardizing this willingness to engage in DR programs. This poses important questions for the future, to better understand these results and design strategies to overcome potential resistance.

The results also demonstrate, in line with the magnitude of the coefficients, that the gender, regular communication of the reading meter to the energy supplier and concerns on energy importations are particularly relevant aspects to motivate students to defer electricity consumption and participate on DR programs. However, the number and specific context of the participants on the questionnaire was limited which could influence the obtained results and prevent the generalization of the results. As future research the

application of the proposed questionnaire to a larger population with a sample representative of a region or country is envisaged.

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