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Assessing the Electric and Electronic Devices Acquisition in Romania within the Context of Circular Economy Requirements A Poisson Regression Approach

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Abstract. *In this paper, we analyse the factors influencing the purchase frequency of three types of electronic devices and home appliances (mobile phone, TV set, laptop) by Romanian consumers and identifies the stimuli for a consumer behaviour aimed at a responsible getting out of use of electronic equipment and home appliances. Using survey data and a Poisson regression approach, we show that there is a negative relation between the gender of a respondent and the frequency of acquisition of home appliances during the last 5 years – despite that, only in the case of acquiring mobile phones the coefficient is statistically significant. Furthermore compared to individuals that have post-graduate studies (master's degree or PhD), the high-school graduates present a greater inclination towards the more frequent purchase of mobile phones; as for age, the number of acquisitions of a new electronic device or home appliance, regardless of its nature, this decreases as age increases; referring to the acquisition manner, the persons who buy exclusively from specialized stores purchase less phones, PC-s and TV sets as compared to a person that adopts both manners (physical store and online). Concerning the stimuli for collecting, the research results show that these do not influence the purchase decision of a new equipment, regardless of its type, the results of Poisson regression being statistically insignificant for the analysed sample. The results of our paper show that there is no strong binding between the purchase determinants of new equipment and responsible recycling of old equipment.*

Keywords: circular economy, consumer behaviour, electronic waste, recycling, Poisson regression.

Introduction

The evolution of consumerist economy during the last two decades has an increasing trend, bringing about an explosion of electronic devices and home appliances consumption, mainly due to the continuous increase of population living standard and the massive migration of people from rural to urban areas. By default, the increase in consuming this type of products and the consumers' preference for improved technology have generated an accelerated growth of electronic devices

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and home appliances related waste, both in volume and in structure, equally on the part of consumers and producers.

Given these circumstances, considering the harmful effects of inadequately managed waste onto the quality of life (pollution of air, water, and soil) and the desire of the world states to ensure a sustainable economic development, international decision-makers in public policy matters confronted a dire need to identify concrete solutions to reduce waste and/or manage waste such that the negative impact on the environment to be reduced.

It is difficult to conceive a sustainable social-economic development without an adequate management of waste and secondary products. Circular economy initially appeared as a response to this challenge, but at present it is far more than that. Within a Communication from the European Commission (2015) on this topic, circular economy is defined as the economy "where the value of products, materials and resources is maintained in the economy for as long as possible, and the generation of waste minimized". The transit towards circular economy means the break of classical linear cycle – raw materials > processing > consumption > waste – and the decrease in the consumption of natural resources and generated waste (Jora et al., 2018). Circular economy also means sustainable business models that use the resources at maximum efficiency. It may become a source of labour opportunities, one estimating that the adoption of circular economy practices can lead to more than 6 million new jobs globally (ILO, 2018).

Nowadays it has become obvious that successfully implementing circular economy should refer to two inter-dependent domains where adjusted behaviour is needed: industrial/production and residential/household. On the one hand, at producers' level (industrial) the way a good is designed from the perspective of its reparability and/or reutilization may influence the behaviour of that good's consumer respectively related to its reutilization until the end of utilization period and/or its recycling after reaching the utilization duration. On the other hand, transition from linear to circular economy (that equally implies reparability, reutilization, and recycling) becomes possible only through the implication of all interested parties into this process of transition (government, producer, consumer, society).

An important category of waste is represented by that generated by electric and electronic devices (EED). The fast-technologic advance and moral wearing out led to an explosive growth of production and consumption of electric and electronic devices, and, as such, to a growth of related waste. This is why almost all world countries have created national laws referring to the reutilization, recycling, and to other forms of recovery of their components. This type of waste represents a complex mix of materials, some of them valuable, and others whose deficient management or mix with home waste could bring about major damage to the environment and health. Within the Emergency Ordinance 5/2015 (a piece of Romanian legislation) regarding electric and electronic devices related waste, these are defined as "electric and electronic devices that represent waste, including components, parts and consumables that are part of the product at the moment it becomes waste".

All over the world, the recycling rates of this waste are reduced, and within the European Union (EU), which is considered as the world leader in recycling electronic waste, only 35% of electronic waste is reported as being adequately collected and recycled (UNEP, 2022). According to Eurostat (2020), in Romania the recycling rate of electronic waste was only 25% in 2017, placing this country on the 26th place out of 27 in the EU. At the opposite side, one finds EU member states with a level of recycling rate of electronic waste higher than 50% (Croatia – 81.3%, Estonia – 69.8%, Bulgaria – 68.8%, Hungary – 51.1%, Austria – 50.1%). In this context, it seems that, on

a global scale, the national approaches regarding the necessity to recycle electronic devices and home appliances have not generated the expected outcome.

The paper aims towards exploring on the one side, the determining factors of acquisition frequency of three types of electronic devices and home appliances (mobile phone, TV, laptop) by the Romanian consumers, and then to identify the stimuli for a conduct of responsible disposing of electronic devices and home appliances, on the other side. The main research problem is related to pondering on the ecological awareness of the Romanian consumers, their knowledge of the relevant Romanian/EU legislation (e.g., within the context of the ambitious "Green Deal" provisions) and propensity to comply with it, as well as to placing environment preservation / climate change tacking related rationales (e.g., the ecological impact of the electric/electronic devices already in use relative to the desired new ones) amongst the factors that shape the acquisition decisions and those pertaining to the responsible manners to get rid of old pieces equipment etc. In doing so, the study brings novelty by focusing on one of the most dynamic segments of consumer goods (the electric/electronic ones), even more interesting in a period of digital transformation that puts its imprint on both consumer experiences and production processes, making circular economy requirements equally important for industries and households. The paper is structured as follows: the first section surveys the specialized literature on circular economy, on the importance of waste management and on the consumers' behaviour regarding selective recycling; section two is devoted to the presentation of the research methodology, and also to Poisson regressions applied to the set of data gathered by the 400 questionnaires filled in by participants; the third section represents the analysis of the sample/questionnaire results; the fourth one analyses the results of Poisson regressions; the last section is dedicated to the conclusions.

Literature review

The concept of circular economy aroused the interest of specialists in various fields, this being sustained by the numerous scientific papers published over the years. The scrutiny of this concept starts with Boulding (1966), being furthered, among others, by Leontief (1991), who holds that one must make a clear distinction between technology and economy for the specialists to conduct reasonable analyses that are meant to lead to circular economy processes. Later, the concept of circular economy passed through different applied approaches, being notably enrooted, for instance, within the UN resolution called Agenda 2030.

Kirchherr et al. (2017) analyse 114 definitions of circular economy, converging to the fact that this represents a combination of reduction, reutilization, and recycling processes, and the main goal is connecting economic prosperity with environment quality, the impact onto social equity and future generations being also mentioned. According to Pan et al. (2022) and Bressanelli et al. (2020), circular economy is understood as a model pertaining to the larger family of sustainable economic development, which replaces traditional development relying on resources consumption and waste generation, aiming instead for the significant lowering of the demand for natural resources, thus leading to a decreased level of waste from raw materials extraction, packaging, and transportation (ILO, 2019). As for an enhanced view on circular economy, this is supposed to require designing a transition route towards circular value chains that also consider socially inclusive political instruments (UNEP, 2022). Nevertheless, the need for more accurate theorizing of such a complex and evolving concept is emphasized by Kalmykova et al. (2018) and Korhonen et al. (2018).

Turning to a narrower circular economy subfield, that of waste management (including the waste coming from electric and electronic devices), McMahon et al. (2019) refer to the legislation

of EU member states focused on reuse and extension of equipment life cycles, pointing to the need to incentivize both consumers and producers in this regard. Pérez-Belis et al. (2015) analyse the specialized literature for a period of 22 years (1992-2014), focusing on issues such as waste generation and regulation, considering the social and economic aspects of these options, which constitute a new challenge for pro-environment decision-making political factors, as duly noted by Needhidasan et al. (2014). In the same vein, Babu et al. (2007) and Puckett et al. (2002) show that electronic waste represents one of the major problems worldwide, since the production of electric and electronic devices reached an unprecedented level, with the so-called Fourth Industrial Revolution accelerating this tendency, while creating both synergies and strife between the green and digital transformations (Jora et al., 2022).

In a paper by a leading organization in the field of circular economy, Ellen MacArthur Foundation (2018) presents a series of actions that should be considered by industries in order to transit from linear to circular economy. The development of a circular economy refers to the way of projecting, realizing, and utilizing electronic products of wide use. The adaptation of business models specific to circular economy may assist, to a larger extent, the development of a new type of relation with the consumer. Despite all these, nowadays, on the electronic devices market there are more factors that discourage the users of electronic products to refurbish the used devices. In an analysis by Townsend (2011), the importance of consumer awareness regarding the "electronic waste dilemma" is underlined, observing the role of regulations and policies developed by governments, in junction with those who manufacture these products, and the way these initiatives contribute to the modelling of present day and future electric/electronic waste management practices.

With regard to researches investigating the perception and awareness on circular economy in different countries of the world, one may note the contributions from van Langen et al. (2021), with a study based upon a questionnaire applied to researchers, economists, and business persons mainly from the EU, but also from some non-EU countries, showing that the three above-mentioned socio-professional groups have a common vision referring to the circular economy at the stage of transition, but the implementation of circular economy is costly both for consumers and companies, a reason why the political intervention has a significant role in the development of a positive and lasting image for circular economy in the public conscience. Mykkänen and Repo (2021), in analysing the responses form a survey done in 2018, in Finland, show that the perspectives of the consumers vary from one domain to another and the responsibility for the reutilization of electronic products and other largely used goods is attributed mainly to consumers. A paper of Cordova-Pizarro et al. (2021) analyses the consumer behaviour regarding electronic products in Mexico, pointing that this domain is less touched in Latin America, and showing that, trying to extend the life-span of electronic products, the Mexican consumers consider the circularity of the product – including the case of reutilization of mobile phones, and if they would receive some stimuli by public services in order to value the interest of consumers, then electronic industry could direct faster towards a model of circular economy. According to Atlason et al. (2017), who present three scenarios (reutilization, recycling and re-manufacturing) and two models of collection (door-to-door and depositing to a collection place), considering eight types of electric devices and electronic appliances, the results show that the preferences of the users are largely matched with the concept of circular economy, while age, sex, and education level are relevant to this type of analyses. Also, Botelho et al. (2016) analyse the perception and acceptability of consumers related to a number of alternative schemas of electric and electronic devices waste collection in Portugal, shows that the social-demographic and informational factors influenced the behaviour of

respondents related to waste disposal, 54% reporting that the lack of information and collection places close to them is decisive in their reluctance towards circular behaviours. As for the views of the Romanian consumers regarding circular economy, this is analysed by Lakatos et al. (2016), who, by means of an online questionnaire, have tested the extent to which the respondents adopt a responsible attitude in promoting circular economy. The results show that the consumers have a positive attitude towards environment protection, but the consumption actions are not always in accordance with the attitude towards the environment.

Turning from the user's perspective to that of the industry, Juchneski (2022) emphasizes that despite the existence of some researches within this field, and also laws and regulations that support the utilization of used materials within the production process, those that produce electronic devices do not pay high attention to recycling and recovery of materials for the production process of new components. Gama et al. (2016) also present a series of examples concerning the political and legal approaches that have an impact onto circular economy from the perspective of industry, noticing the problems associated with the improvement of product design, the sustainable management within the supply chain, focusing on the increase in corporate responsibility regarding circular processes and to the elaboration of strategies about circularity.

Considering the above-mentioned literature review we test one hypothesis:

H0: The acquisition of a new phone or a new computer/laptop or tablet is sensitive to consumer-related variables such as Gender, Education, or previous behaviour.

Methodology

Throughout this study we will use Poisson regression as an estimation technique. This approach is adapted to model a discrete explanatory variable of the "count data" type, that is, that variable quantifies the number of occurrences of a given event in a fixed time interval for a representative sample of volume n.

We will first present some properties of the distribution, given that the dependent variable is assumed to be a realization of it. Thus, the Poisson distribution is a discrete distribution that measures the probability of a certain number of events occurring in a certain period. The discrete random variable X is said to follow a Poisson distribution law of parameter λ if it has the following form:

$$f(x) = \begin{cases} e^{-\lambda}\dfrac{\lambda^x}{x!},\ x \in N,\ \lambda > 0 \\ 0,\ otherwise \end{cases} \qquad (1)$$

The shape of the Poisson distribution depends on the values of the parameter λ as can be seen in Figure no. 1.

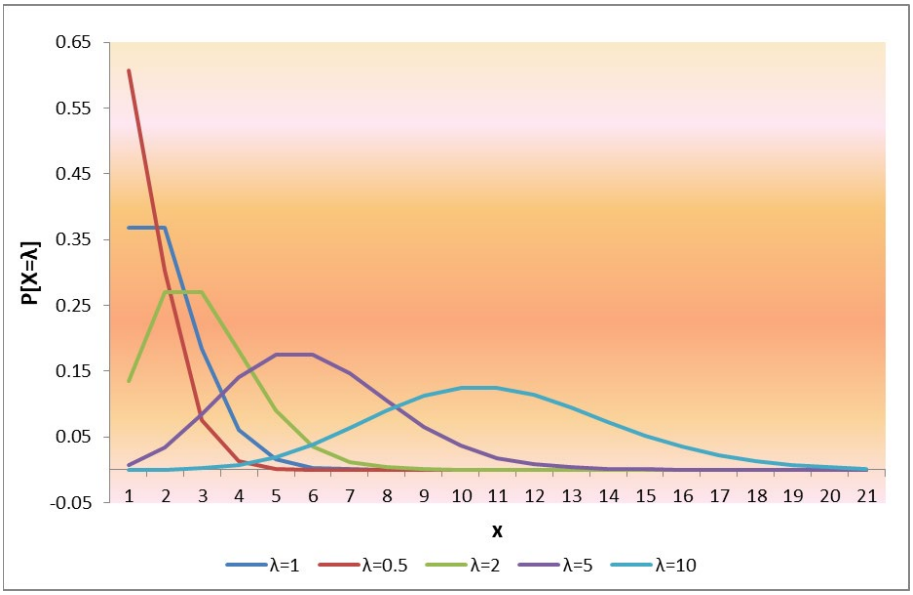


Figure 1. PFD of Poisson distribution

Source: own calculation.

It can be seen very clearly from the figure above that the shape of the distribution density of the Poisson distribution depends on the values of the parameter λ. In fact, using the Poisson distribution property it can be shown that its mean and variance are equal, i.e. E [X] = Var [X] = λ. Let us consider that we have k independent variables denoted (X_1, X_2,, X_k) belonging to a statistical sample consisting of n subjects. For subject i ∈ {1, 2, ..., n} we have attached the realizations of the independent variables, xi = (x_{1i}, x_{2i},..., x_{ki}) but also the realization y_i, which belongs to a population with a Poisson distribution with mean λ_i. So the dependent variable Y = (y_1, y_2,..., y_n) can be considered as the realization of independent random variables that follow a Poisson distribution. The Poisson regression specification relates the parameter λ_i to the realizations of the independent variables, xi = (x_{1i}, x_{2i},..., x_{ki}):

$$\log(\lambda_i) = \beta_1 x_{i1} + \cdots + \beta_k x_{ik} \quad (2)$$

The estimation of the parameters β = (β_1,..., β_k) of size (k × 1) is performed using the maximum likelihood method. Thus, starting from the premise that the realizations of the explanatory variables, respectively of the explained one, are independent, we can calculate the joint conditional probability distribution as a product of the individual conditional probability distributions:

$$f(y_1, \ldots, y_n | x_1, \ldots, x_n; \beta) = \prod_{i=1}^{n} f(y_i | x_1, \ldots, x_n; \beta) \quad (3)$$

We will define the likelihood function as follows:

$$L(\beta; Y, X) = \prod_{i=1}^{n} \frac{e^{-\lambda_i} (\lambda_i)^{y_i}}{y_i!} \quad (4)$$

The maximum likelihood method starts from the principle that the β parameters should maximize the probability that the specified analytical model (Poisson regression in the present case) is the one that generates the empirical results:

$$\hat{\beta} = argmax_{\beta} L(\beta; Y, X) \quad (5)$$

Solving the optimization program highlighted in relation (5) cannot be done analytically, and it is necessary to use a numerical program, such as the Newton-Raphson algorithm.

Results and discussions

Our paper analyses the behaviour of Romanian consumer related to the frequency of acquisition of three types of electronic devices and home appliances (phone, TV, laptop/computer/tablet), and also the stimulating factors for responsibly getting out of use the electronic equipment and home appliances.

The questionnaire was applied online, between the 1st and 20th September 2022, and the respondents are individuals from Bucharest and Ilfov, 40% men, 60% women, aged between 18 and 71. The respondents' distribution according to study level is as follows: 38% high school, 32% university, 24% post-graduate, 6% PhD and post-doctorate.

The dependent variables in regression analysis rely upon the number of acquisitions of a phone, laptop/computer/tablet and of a TV set during the last 5 years.

We notice that:

- 26.75% of the respondents have bought at least one mobile/smart phone during the last 5 years, 42% of the respondents have bought 2 mobile phones during the last 5 years, and 19% even three of them. Only 1.5% have bought none during the mentioned period.
- More than half of the respondents have bought at least one laptop/tablet during the last 5 years, 17.7% have bought two, and 19% even three. 25.75% of the respondents have bought none during the mentioned period, which means that more than three quarters of the respondents have bought at least one equipment of this kind. This result may be also explained by the fact that the period was identical to that of COVID-19, during which many people worked remote, and the schools and universities had online activities;
- Related to TV sets acquisitions, more than half of the respondents bought at least one of this kind during the mentioned period, and 22.7% bought even two. The results are not at all surprising – TV sets are among the best bought equipment from our country. 18.25% of those who answered the questionnaire bought no TV set during the last 5 years.

Furthermore, the explanatory variables are presented in Table 1 and were selected according to their distribution, and also to the relative influence they have in explaining consumption behaviour. At the same time, we made sure from the beginning that the value of correlation coefficient in any pair of explicative variables does not exceed the level of 40%, in order to avoid potential issues related to multi-collinearity.

Table 1. Descriptive statistics for explicative variables of regression

Question	Variants	Distribution
Gender	Feminine	241
	Masculine	159
Last graduated level?	High school	152
	University	127
	Master's degree or PhD	121
Age?	Average value	35.4 years

Question	Variants	Distribution
Where have you bought electronic devices and home appliances from?	Only specialized stores	89
	Only online	135
	Both	176
Which are your reasons for keeping at home defective or unfunctional electric devices or home appliances?	I do not own such equipment	238
	Comfort	162
Which of the following situations would motivate you to responsibly get out of use old electronic devices or home appliances you have at home?	Easy access to collection places	34
	Nothing	37
	Vouchers	259
	Pickup from home by a specialized company	70
How important do you find at present the collection of waste and rubbish (plastic, paper, glass, textile, batteries, electric equipment, home appliances)?	Important	66
	Slightly important	22
	Very important	312
To which extent are you aware of the laws regarding the selective management of electronic devices waste or home appliances waste?	Not at all	23
	Little	88
	Some extent	198
	High extent	91

Source: own calculation.

In Table 2 we present the results of Poisson Regression for all three specifications. Thus, in Model 1 we have as dependent variable the number of acquisitions of a new phone during the last 5 years. In Model 2 the dependent variable is the number of acquisitions of a new laptop/computer/tablet (PC-s) during the last 5 years, while Model 3 uses as dependent variable the number of acquisitions of a TV set during the last 5 years.

Based on Table 2 results we may conclude that the acquisition of a new phone or a new computer/laptop or tablet is to a higher extent explained by the realizations of explicative variables, as compared to the acquisition of a new TV set. The value of Pseudo R-squared is 28% for Model 1 and 27% for Model 2, which are rather high values if we compare with Louviere (2000) who showed that a 20% value for Pseudo R-squared is equivalent with an adjusted R-squared for an OLS-type model of 70%. This fact renders a highest accuracy to results and conclusions that rely upon them.

One may notice a negative relation between the gender of a respondent and the frequency of home appliances acquisitions during the last 5 years. Despite that, only in the case of phone acquisitions the coefficient is statistically relevant. Thus, if a subject is feminine, the average number of phones bought during the last five years is lowered with 19% (1-e-0.213) caeteris paribus. This result shows that women have a higher reticence regarding the frequent acquisitions of mobile phones, which may be associated with a higher responsibility, according to Roy Dholakia (1999).

Table 2. Regression results

Question	Variants	Model 1	Model 2	Model 3
Gender	Female	-0.213***	-0.148	-0.103
	Male	0.000	0.000	0.000
Last graduated level?	High school	0.174*	-0.041	-0.010
	University	0.745	0.089	0.012
	Master's degree or PhD	0.000	0.000	0.000
Age?	Average value	-0.007**	-0.012***	-0.001*

Question	Variants	Model 1	Model 2	Model 3
Where have you bought electronic devices and home appliances from?	Only specialized stores	-0.181*	-0.163*	-0.049*
	Only online	-0.055	0.024	-0.149
	Both	0.000	0.000	0.000
Which are your reasons for keeping at home defective or unfunctional electric devices or home appliances?	I do not own such equipment	0.000	0.000	0.000
	Comfort	-0.066	0.091*	-0.103
Which of the following situations would motivate you to responsibly get out of use old electronic devices or home appliances you have at home?	Easy access to collection places	-0.133	-0.004	0.126
	Nothing	0.000	0.000	0.000
	Vouchers	-0.161	-0.142	0.034
	Pickup from home by a specialized company	-0.075	0.154	0.104
How important do you find at present the collection of waste and rubbish (plastic, paper, glass, textile, batteries, electric equipment, home appliances)?	Important	0.138	0.076	0.077
	Slightly important	-0.005	-0.185	-0.015
	Very important	0.000	0.000	0.000
To which extent are you aware of the laws regarding the selective management of electronic devices waste or home appliances waste?	Not at all	-0.128*	-0.284	-0.062
	Little	-0.122*	-0.370**	-0.135
	Some extent	-0.133	-0.239**	-0.126
	High extent	0.000	0.000	0.000
Observations		349	349	349
Pseudo R-squared		0.28	0.27	0.07

Source: own calculation.

Relative to people with post-graduate studies (master' degree or PhD), the person with high-school studies presents a higher propensity towards the more frequent acquisition of new mobile phones. In other words, a person with higher studies does not have the tendency of frequently changing the mobile phone with a new one. Men with high-school studies seem to be more inclined to frequently buy mobile phones, according to the results of regression 1. Like in the case of gender, the results for models 2 and 3 are not statistically significant.

Unlike the first two variables, in the case of age the number of acquisitions of a new electronic device or home appliance, no matter its nature, decreases as the age increases. The impact coefficient is higher in absolute values for model 2 and shows us that, for a one unit increase in age, the average number of phones bought during the last 5 years decreases with around 0.7%, that of PC-s with 1.19%, and that of TV sets is insignificant.

The stimuli for collecting do not influence the buying decision of a new equipment. No matter its type, the results of Poisson regression being statistically insignificant related to the analysed sample. Thus, not even the vouchers offered for an old equipment do not significantly influence the purchase decision of a new electronic device or home appliance. Very likely, Romania has not reached such a sophisticated level of an awareness for the importance of recycling, such that the purchase decision to be linked to the concept of sustainable recycling.

As for the acquisition manner, persons who buy exclusively from specialized stores purchase with an average of 16.56% less phones, with 15.04% less PC-s, and with 4.78% less TV sets, as compared to a person who uses both types of acquisition (stores and online).

People who like comfort as related to recycling have the propensity to buy PC-s more rarely, but this characteristic is neutral when it comes to the decision of purchasing a phone or a TV set, the coefficients of Poisson regression being statistically insignificant.

The subjects who declared that they keep at home defective or unfunctional electronic devices or home appliances purchase more frequently laptops/PC-s, but not mobile new phones or TV sets. Moreover, the knowledge regarding the laws for selective management of electric and home appliances waste do not lead to a decrease in the frequency of their acquisition, but to the opposite. Thus, people who are not at all aware of these laws or have a minor knowledge of them have the propensity of buying more rarely new mobile phones or PC-s.

Therefore, also there is a high awareness for the importance of selective recycling of waste and there is a rather good level of knowledge regarding the laws that refer to selective management of electronic devices waste or home appliances waste, most of the people are still not willing to buy reconditioned devices and adopt an ecologically responsible behaviour inasmuch as it does not demand too much effort (specialized operators of local authorities pick up from households the out of use or unfunctional equipment, containers are close from home etc.).

The results of our study show that there is no strong statistical binding between the determinants of buying new equipment and the responsible recycling of old equipment. The fact that almost 40% of the respondents keep at home old electronic devices or home appliances for different reasons of with different intentions, although they purchase new ones, means that there is a need for more national campaigns of awareness for the importance of recycling and responsible getting out of use of electronic devices and home appliances.

Conclusion

Technological development and the continuously growing moral depreciation led to an explosive increase of electric and electronic waste. This is why almost all world states, including Romania, have elaborated national legislation referring to the reutilization, recycling and other forms of recovery for materials that compose them. Recycling of electronic devices and home appliances is very important, because this type of waste represent a complex mix of materials, some of them valuable, and others could generate major prejudices on the environment and health if defectively managed or mixed with households' waste.

Our research shows that, although during the last three years in Bucharest the replacement of electronic devices and home appliances is accomplished at lower and lower periods of time, and their moral depreciation is the second reason for purchasing new ones (equally with the reason that they become defective), the responsible getting out of use is still hindered. Although there is a high awareness for selective recycling of waste and a rather good level of knowledge of the laws referring to selective management of electronic devices waste or home appliances waste, most of the people are not willing to adopt an ecologically responsible behaviour, only as much as it does not demand high efforts. Comfort is the main reason for the Romanian consumer to still keep at home used equipment, and offering vouchers for new equipment purchases is not a sufficiently attractive stimulus for handing them over to stores. The information campaigns may contribute also to the increase in awareness regarding the danger of accumulating electronic devices waste or home appliances waste. Our study, relying on the responses of 400 people, also highlights a lack of interest of the Romanian consumer for purchasing reconditioned electronic devices and home appliances. This leads to the conclusion that the circularity of these products is not an option for Romanian consumers, at least for the moment. In summary, the hypothesis H0 is validated by the data, indicating that some patterns in consumer behaviour and their demographic characteristics are influencing the propensity to buy an electronic equipment.

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