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Analysis of the impact of the age structure transition on electricity consumption in Brazilian households

Análise do impacto da transição da estrutura etária no consumo de energia elétrica domiciliar do Brasil

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ABSTRACT: The study of consumption in the relationship between Population and Environment (P-E) has been gaining prominence and notoriety since it is being proved that this is a variable that is extremely correlated with demographic dynamics. The objective of this study is to analyze the consumption of household electricity per capita by stages of the household life cycle in Brazil and to simulate the behavior of energy consumption considering changes in the household age structure. The proposed methodology consists of measuring specific consumption rates by the phase of the household's life cycle and, through direct standardization techniques, verifying the level of energy consumption in case Brazil had other age structures in its households. The database used in this research was the 2008/2009 Consumer Expenditure Survey. The results indicate that the level of household electricity consumption per capita presented by Brazil in 2009 would decrease by 2.6 kWh if the country had the age structure observed in 1970. As a conclusion from the results, there will likely be an increase in the consumption of electricity when the households will have a more aged structure, by the age of the head of the household. That means consumption should increase, in part, due to population aging. This research corroborates the demystification of Malthusianism, whose main idea attaches too much importance to the population volume in the environmental debate to the detriment of other demographic variables, as well as strengthens the need to create and consolidate a systematic line of research on "consumer demography".

Keywords: population-environment; consumption; demographic transition; electricity.

RESUMO: O estudo do consumo na relação entre População e Ambiente (P-A) vem ganhando destaque e notoriedade, já que se vem comprovando que se trata de uma variável que é extremamente correlacionada com a dinâmica demográfica. Dito isso, este trabalho teve como objetivo analisar o consumo de energia elétrica domiciliar per capita por estágios do ciclo de vida do domicílio no Brasil e simular o comportamento do consumo energético considerando as mudanças na estrutura etária domiciliar. A metodologia proposta consistiu em mensurar taxas específicas de consumo por fase do ciclo de vida do domicílio e, por meio de técnicas de padronização direta, verificar o nível de consumo energético caso o Brasil apresentasse outras estruturas etárias em seus domicílios. O banco de dados utilizado foi a Pesquisa de Orçamento Familiares 2008/2009. Quanto aos resultados, eles indicaram que o nível de consumo de energia elétrica domiciliar per capita apresentado pelo Brasil em 2009 diminuiria em 2,6 kWh se o país possuísse a estrutura etária observada em 1970. Como conclusão, a partir dos resultados, tem-se que deve haver um aumento do consumo de energia elétrica quando os domicílios apresentarem uma estrutura por idade do chefe mais envelhecida, ou seja, um maior consumo deve surgir, em parte, devido ao envelhecimento populacional. Portanto, esta pesquisa corrobora com a desmistificação do malthusianismo, cuja ideia principal atribui importância demasiada no volume populacional no debate ambiental em detrimento de outras varáveis demográficas, bem como fortalece a necessidade de se criar e consolidar uma linha de pesquisa sistemática da “demografia do consumo”.

Palavras-chave: população-ambiente; consumo; transição demográfica; energia elétrica.

1. Introduction

Environmental impact, sustainable development and the green economy are subjects that have been extensively discussed and researched in the scientific community during the last decades, mainly with regard to the role of humans in the global climate change processes. The understanding of the responsibility of humans in this climate change process is the majority among scientists, as referenced in successive reports of the Intergovernmental Panel on Climate Change - IPCC, notably the 4th IPCC Report (2007) (Hogan, 2009). In this context, the need to understand the human responsibility and component in environmental processes has become prevalent in conferences and global forums related to the theme.

However, Hogan (2009) states that the humanities have not always been properly present in the debate and that, specifically in Brazil, the human dimensions have only recently been incorporated into studies and research related to global environmental change.

Historically, the demographic component was inserted into the environmental issue in light of Malthusianism, whose main idea was that human survival was threatened by population growth due to a hypothetical food shortage or, more recently, under the aspect of economic growth. The author of this theory, Thomas Malthus, in his famous postulate dating from the end of the 18th century (Malthus, 1798), projected that population growth was faster than food production and that there would be no natural resources available to subsidize so many people. Malthus was one of the first authors to relate the population and environment dimensions, a debate thatwas incorporated into the scope of the study of demographic science with development over time, and a field of research called Population-Environment (P-E) was established (D’Antona, 2017).

Despite the relevant impact and influence on society and the ideologies that guided population policies in the 19th and 20th centuries (Hogan *et al.*, 2010), Malthus' predictions did not materialize as he predicted, and history itself has shown that the relationship between population increase and the depletion of natural resources does not present linear behavior.

With the demographic transition process[1] already advanced in much of the world, fertility rates have fallen below population replacement levels, and a decrease in birth rates has already occurred a few decades ago in most countries. Thus, population growth rates in some countries are already relatively low, with cases even of countries with decreasing population (UN, 2019). Therefore, with the decrease in population growth, especially in developed countries that contribute significantly to greenhouse gas emissions, it was expected that the effects of man on nature would also decrease. However, what we saw is just the opposite (Mello & Hogan, 2007), because with the reduction in the rate of growth of the world population, there was a simultaneous increase in environmental pressure. In other words, population growth alone would not explain the pressures on the environment, as they were supposed to (Hogan, 2007; Hogan *et al*., 2010; Ojima, 2011).

Thus, despite significant advances in the literature dedicated to the theme, studies are still found that address the population-environment (P-E) from this Malthusian approach, in which the depletion of natural resources and even climate change would be directly related to population growth (Hogan, 2007; Ojima, 2011). An example of this is a widely reported media article published by The Lancet and that highlights that "the [population] projections of shrinking the world population have positive implications for the environment, climate change and food production" (Vollset *et al*., 2020, p. 2, our translation). Likewise, models projecting climate change scenarios always incorporate absolute population growth as a negative forcing variable for climate change (Jiang & Hardee, 2011; Ojima, 2011).

It is important to note that this research does not deny that population size is an important factor in pressure on the environment. It is to be expected that a population of eight billion people will need more resources than one billion. The criticism made here is the reductionism and fragility of this discourse when other demographic factors are not incorporated into this relationship, especially in a context in which projections predict a continuing reduction in fertility, a decrease in growth, and even a reduction in population in several countries.

Thus, the objective of this article is to present evidence for the need to incorporate other aspects of demographic dynamics into the analysis of P-E. Therefore, in light of recent literature on the role of population in environmental performance (Guzman et al., 2009; Martine & Schensul, 2013), we will discuss this as a post-transition context, a period characterized by very low (and potentially negative) population growth in some cases and an aging age structure, which can have significant environmental impacts. Martine (2012, p.12) asserts that "the demographic dynamics are much more complex and its importance in ongoing environmental processes

[1] The Demographic Transition Theory explains how populations went from a pre-modern condition of stability with high mortality and fertility, to another almost stable post-modern condition with low mortality and fertility. The main consequences of the Demographic Transition are the decrease in population growth and the aging of its age structure.

is much greater than the mere absolute numbers". In fact, to limit the demographic component in the environmental debate to population size alone is to waste all the potential that demographic analysis could offer for understanding the P-E relationship.

With the evolution of the discussion in the academic environment and the growing understanding that it is necessary to overcome the hegemonic discourse of Malthusianism, at least in the field of demography, questions have arisen about which other demographic factors would assume importance in the issue of global climate change. Martine (2012) highlights the importance of expanding the debate by incorporating other demographic variables such as fertility, mortality, morbidity, migration, nuptiality and age structure.

It is in this context that demographics pays attention to the population's consumption pattern to better understand the P-E relationship, as reported by De Sherbinin & Curran (2004). According to the authors, consumption is not new in environmental studies. However, this component is approached in environmental discourse in a superficial or even incorrect manner (De Sherbinin & Curran; 2004), mixed, and even with ideological biases, in which there is not proper analysis of the consumption variable beyond Malthusian optics. The proposal of population-environment studies to understand the consumption of other demographic variables is characterized in a fruitful field of study, and perhaps this is the greatest contribution of demography to environmental sciences, which may bring great subsidies to mitigate and adapt to global environmental changes. For a better understanding of the insertion of the consumption variable in the Population and Environment debate and how it happened historically, see Mello & Sathler (2015).

It is in this context that demographic research understood that the importance of consumption in P-E studies is not only due to a critique of the current economic development model, but mainly to the fact that consumption is a variable whose behavior is intrinsically related to population dynamics. Demographic transition, age structure, family composition, life expectancy, gender equity, migration flows, urbanization, family composition and size, and other demographic dimensions are of fundamental importance in understanding consumption patterns and should be incorporated into estimates of changes rather than absolute population volume (Pebley, 1998; Liddle, 2011; Modesto, 2011; Martine, 2012), which in practice contributes more to maintaining the environmental status quo.

Thus, given that Brazil and a large partof the world are experiencing profound demographic changes that condition the aging of its population, changes in family arrangements, and consequently a trend towards fewer people per household, the demographic dynamics is a major factor in defining the standard and level of aggregate consumption and, therefore, has consequent reflexes on the pressure exerted by the population on the environment.

Several works have carried out a theoretical-analytical exercise on the theme, giving consumption a leading role in discussing the impact of population on the environment. In addition to the seminal work by De Sherbinin & Curran (2004) already mentioned, similar conclusions can be drawn from Carmo (2007); Mello & Hogan (2007); Mello (2009); Satterthwaite (2009); Martine (2009); Hogan *et al.* (2010); Liddle & Lung (2010); Liddle (2011); Modesto (2011); Ojima (2011); Martine *et al.* (2012); and Ojima (2012). However, although this literature brings a significant advance to the emerging debate, De Sherbinin & Curran (2004) affirm that there are few methodological studies that operationalize and quantify the effects of demographic dynamics on aggregate consumption and its potential environmental effects. The authors also emphasize the major methodological challenges in the area, suggesting some options for the scale of analysis and consumption metrics, for example. It is in this methodological gap that this work seeks to insert itself and contribute to the discussion.

According to Neomalthusian logic, the decreasing the rate of population growth and the absolute population volume should induce a lower demand for natural resources (Hogan *et al*., 2010; Mello & Sathler, 2015). However, the hypothesis to be tested here is how the decreasing and maintaining low fertility levels can have a very opposite effect, at least in the short to medium term. In other words, even with fewer people in a population, only the transition of the population's age structure and other demographic arrangements could exert greater pressure and demand on natural resources, increasing aggregate consumption. Thus, based on this theoretical framework, the objective of this study is to analyze the per capita consumption of household electricity considering the stages of the family/inhabitant life cycle in Brazil and to standardize the behavior of aggregate consumption with the aging of the population/inhabitant.

As mentioned previously, the potential of methodological options to understand consumption based on demographic variables is still being explored. In this sense, this work adopted the following methodological options: the Pesquisa de Orçamento Familiar (Family Budget Survey) - *POF* 2008/2009 was used as a data source; electricity consumption was chosen as the consumption metric; the household was considered most appropriate as the scale of analysis; the age of the head of household was suggested to demographically characterize the household; and, finally, the Direct Rate Demographic Standardization technique was proposed to achieve the proposed objective. The theories that justified the choices made are better discussed in topic 3 of the paper.

Thus, it is expected to corroborate the discussion about the relationship between changes in the age structure and consumption, as well as to argue about the relationships between the demographic transition, new family arrangements, and the increase in the number of households in the consumption pattern.

2. Demographic dynamics and consumption: converging points

The Brazilian population began the process of demographic transition from the end of the first half of the 20^{th} century, leaving a regime of high mortality and fertility rates for low rates. In addition, life expectancy at birth increased by more than 30 years in the last 60 years, while the Total Fertility Rate (TFT)[2] that was 6.2 children per woman in 1960 reached the mark of 1.8 in 2010 (IBGE, 2013). The declines in mortality and especially in fertility caused a profound and probably irreversible change

[2] The TFT represents the average number of children that a woman would have at the end of her reproductive period if she experienced the specific fertility rates observed at that time throughout her life.

in the Brazilian age structure. Thus, the population aged 60 and over, which represented 5.1% of the total population in 1970, rose to 10.8% in 2010 and, according to projections, is expected to represent about 25% of the population by the middle of the 21st century.

As a result, another consequence of changing age structure is the aging of families and/or households. In other words, with an older age structure and fewer children, households are also older. As an indicator of this aging in households, it appears that the average age of the head of household increased from 43.2 in 1991 to 45.6 in 2010 (Ojima *et al*., 2014).

This process of reductions in fertility and mortality rates observed in contemporary societies, as well as their causes and consequences, is called the First Demographic Transition - FDT (Lesthaeghe, 2010). Another related and consequential process of the FDT is the Second Demographic Transition - SDT. This second transformation in demographic patterns is associated with continued decline in fertility, negative growth, increased diversity of unions and family arrangements, disconnection between marriage and procreation, and increased divorces (Lesthaeghe, 2010). One of the striking general characteristics of SDT was its impact on families, changing its structure, behavior and aspirations.

Thus, what was prominently observed in the SDT was a deinstitutionalization of the nuclear family and a greater heterogeneity in family arrangements. There is still a predominance of the "couple with children" household arrangement, but there is a reduction in their relative importance and an increase in single parent arrangements, mainly headed by women, couples without children and single-parent family arrangements (Medeiros & Osório, 2000; Arriagada, 2007).

Another process associated with demographic changes is the reduction in the number of people per household. According to data from the Demographic Census (IBGE, 2010), households in Brazil had an average of 5.3 residents in 1970, reaching 3.3 residents in 2010. In addition, there was a mismatch between population growth and households. While the population grew by an average of 1.77% per year between 1980 and 2010, the number of households shows another growth pattern, with an average annual increase of around 3% per year in the same period. Thus, the population that doubled between 1970 and 2010 today resides in a number of households that more than tripled in the same period. In other words, the growth of households is greater than the population itself. This process of "more households and less people per household" is intrinsically linked to the decline in fertility and population and family aging in Brazil, and constitutes the process of change in the life cycle of Brazilian households.

By verifying these changes in the population dynamics of Brazil caused by FDT and SDT, it is possible to suggest possible variations in the consumption levels of Brazilians resulting from the changing age structure and life cycle of the households (Vanwey *et al*., 2004; Lee *et al*., 2006; Lee & Mason, 2010). Zagheni (2011) showed the different profiles of per capita consumption of different goods and services by age using data from the USA. It was found that consumption of some goods such as gasoline, clothing and food peak in late adulthood (between 50 and 60 years old). On the other hand, other goods have increasing consumption as consumers age, such as natural gas and electricity. Also according to the same survey, the average emissions of carbon dioxide (CO_2) (used as a proxy for consumption of all goods considered) increase with age until the 60 years.

In the same line of results, studies such as those by Lee & Mason (2010), Liddle & Lung (2010) and Liddle (2011) show a general behavior of consumption increasing with age. The peak of consumption generally occurs in the age group between 60 and 70 years, with a subsequent decline. Thus, if the level of consumption is different and increases across the age groups, it is consistent to propose that the transition in the age structure will affect the population's aggregate consumption. Ojima (2012) speculates about this trend that even if the rate of population growth is reduced and even if the population is reduced, there would be an increase in consumption due to the aging population.

One explanation for this behavior is that consumption is a variable derived from personal or family income: the higher the income, the greater the expected consumption. In turn, income, whether individual or family, is also sensitive to the age or age composition of the family. Some studies, such as those by Leone et al. (2010) and Maia & Sakamoto (2014), have tried to explain how demographic changes, especially those related to changes in the structure and composition of households, have cooperated to increase per capita household income in Brazil. In this scenario, the hypothesis raised is that the aging of the population and changes in the structure of families modify the life cycle of the family and intertwine as causes for the increase in per capita income. Therefore, consumption is expected to increase. thus, the discussion between demographic changes and changes in consumption levels is largely due to changes in individual or household income, which in turn is also sensitive to demographic dynamics (Medeiros & Osório, 2000; Liu *et al.,* 2003; Jiang & O'neill, 2007, Yu & Liu, 2007; Barros *et al.,* 2008; Druckman & Jackson, 2008; Lins, 2010; Tung, 2011; Carvalho & Alves, 2012; Martine *et al*., 2012; Silva *et al.*, 2012; Zanon *et al.,* 2013).

Thus, it can be said that changes in the distribution of families by age, type and size have an effect on household consumption, with consequent impacts on the environment and the use of natural resources (Liu *et al.,* 2003; De Sherbinin & Curran, 2004; Yu & Liu, 2007).

3. Methodological proposal: analyzing the "age of households" and consumption

The methodological proposal of this article is to verify if it would be possible to identify consumption differentials considering a demographic characteristic in Brazil and to analyze the consumption behavior if the country presented another demographic structure. But before detailing each step of the methodology, it is necessary to clarify that this work had to make three methodological options: the consumption metric; the unit of analysis; and the locator of the life cycle phase (or demographic characterization) of the households.

The unit of analysis prioritized by the work is the household, since families and/or households are the end users or beneficiaries of most forms of consumption (De Sherbinin & Curran, 2004). According to Tung (2011), a conceptual difficulty in attributing consumption to individuals is that some types of consumption are collective goods and there may be economies of scale within households. In addition, household expenditure surveys, which are the main sources of consumer microdata, generally do not report individual consumption (Tung, 2011). This preference makes sense, as we consider that a large part of an individual's consumption is shared among family members through durable and non--durable goods. Another potential of the household as a unit of analysis is that this scale not only allow capturing the aging process of the population, but also changes in family size and composition (Silva *et al.,* 2012).

The household energy expenditure will be used as the unit of consumption, as it is understood that this metric largely represents the family's lifestyle. The per capita energy consumption of the household will be used to isolate the effect of the number of people in the household. De Sherbin & Curran (2004) present a number of other advantages to its use are raised, such as: it is easy to measure, it is easily converted into other units (joules, calories, watts, etc.), and each unit of energy consumption is environmentally representative in both terms of pollution and emission of greenhouse gases. Penã (2013) and Del Guercio (2015) deeply discuss the pertinence of using electricity consumption as a good approximation or proxy for household consumption, emphasizing the good applicability of this consumption unit, which is closely linked to the emission of gases that accelerate the process of global climate change, and also relate this measure to other variables associated with it, such as: degree of development of the country, family income, period of analysis, household arrangements and birth cohort.

Finally, the last methodological choice is the criterion to locate the household in its stage of the life cycle as an attempt to quantify household aging. This methodological option was based on Life Cycle Thinking (LCT), as it is a useful analytical tool for understanding the relationship between consumption and age structure (Lee *et al*., 2006; Lee & Mason, 2010; Tung, 2011). The basic hypothesis of LCT is that the behavior of people and families, especially consumption, changes as they get older, and this would imply that the consumption profile of a population is conditioned or influenced by its age structure.

This work understands that both behaviors and consumption differ not only by the age of the people in the household, but also by the type of family arrangement. A combination of the ages of the residents and the family arrangement presented is perhaps a more comprehensive indicator when the aim is to analyze changes in consumption patterns (Fernandez, 2006), combining the changes caused by the first and second demographic transitions into a single indicator. However, the interest of this work is only to quantify the age of the household, an approximation to understand what the "age of the household" would be, without considering the family situation or arrangement at this moment[3].

Thus, it is proposed as a summary measure to be able to estimate the "age of the household" from the age of the head of the household. The choice of this indicator is adequate because it can represent the changes in the age structure of the population at household level. Jiang & O'Neill (2007) state that the composition of the population by the age of the head of the household not only reflects the age structure

[3] Considering the relative complexity of the effects of the household arrangement, it will be discussed separately in the results and it is expected to be developed in future researches.

of the population, but also the age composition of the families.

The data used in this work were the microdata from the Family Budget Survey (*POF*) of its lastest edition, carried out between 2008/2009 (*IBGE*, 2009). This research is carried out by the Brazilian Institute of Geography and Statistics (*Instituto Brasileiro de Geografia e Estatística - IBGE*) and aims to obtain information about the structure of budgets (expenses, consumption and income), nutritional status and living conditions of families and the Brazilian population (*IBGE*, 2008), being the basic unit of information collection the private households, being the analysis units the households and individuals. From this research it was possible to extract information about the household structure, as well as the consumption of electric energy in the household.

Thus, the first step was to calculate specific consumption rates (SCR) for each stage of the household life cycle. This SCR refers to the quotient between the amount of electricity consumption per capita of households in a given phase of the life cycle and the number of households in that same phase of the life cycle. Thus, we understand SCR as the average per capita electricity consumption of household according to the phase of its life cycle. In this way, we can represent SCR as:

$$ {}_{n}SCR_{x} = \frac{{}_{n}HECpercap_{x}}{{}_{n}Hou_{x}} $$

In which,

${}_{n}SCR_{x}$ = Specific household electricity consumption rate per capita between ages x and x+n, where these ages refer to the age of the head of the household;

${}_{n}HECpercap_{x}$ = Total amount of household electricity consumption per capita by households between ages x and x+n, where these ages refer to the age of the head of the household;

${}_{n}Hou_{x}$ = Total number of households between ages x and x+n, where these ages refer to the age of the head of the household.

The concept of person-years, which is a measure of the risk exposure to the event to be measured, should be used in the denominator of the demographic rates. The number of people at the middle of the year is used as an estimate of these person-years due to the difficulty of measuring this amount of risk exposure, assuming that the event studied occurs uniformly throughout the year. In the case of this study, the denominator should be understood as households-year, meaning the number of households that contributed to the risk of consuming electricity. Thus, the number of households informed by the survey was used as an estimate of this number of households-year, since the survey takes place over a period of one year. In turn, there is total household electricity consumption per capita in the numerator and the total households in the denominator.

The second stage of the work consisted in calculating an aggregate measure of electricity consumption, defined as Gross household electricity consumption rate per capita - GCR. The interpretation to be given to the GCR is the average amount of household electricity consumption per capita per household and can be represented as follows:

$$ GCR = \frac{HECpercap}{Hou} $$

In which,

GCR = Gross household electricity consumption rate per capita;

HECpercap = Total amount of household electricity consumption per capita;

Hou = Number of households.

The GCR found for Brazil in 2009 was 59.5 kWh, which can be interpreted as the average amount of electricity consumption per capita per household. This is the household's per capita electricity consumption level. The series of SCRs found is represented in Figure 1:

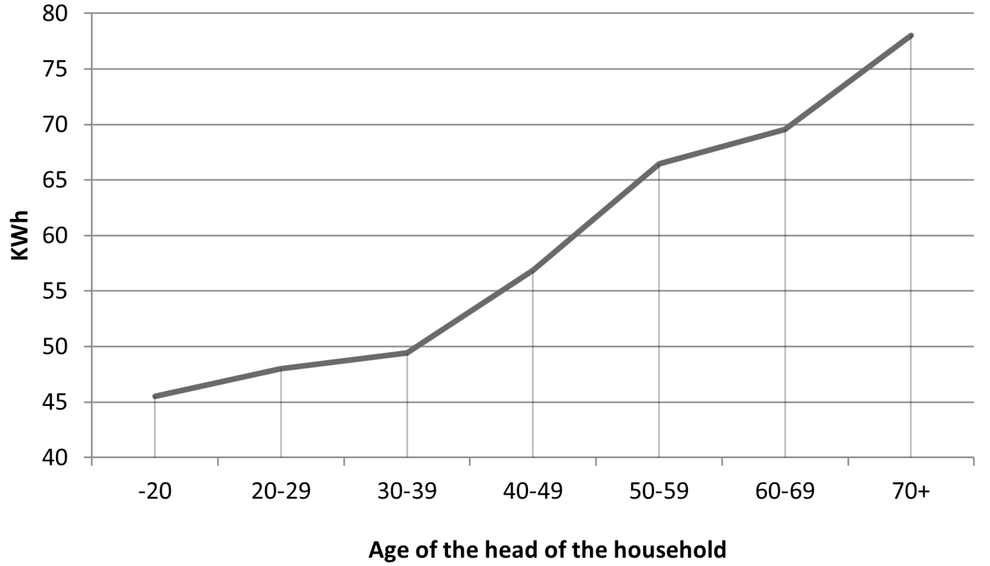

FIGURE 1 – SCR of households by age of head of household, Brazil, 2009.
SOURCE: IBGE (2008), Microdata from the *POF* 2008/2009.

Therefore, it appears that the level of household electricity consumption per capita increases as the head of household gets older. This behavior corroborates the hypothesis raised that consumption is a variable that suffers effects from the population composition and that increases as the households age, remembering that this work is adopting the age of the head of household as a representation of the aging household. This can be explained by the fact that the monetary income of individuals and the aggregate combination of the members of a household generally increases during their lifetime.

Another fact that helps to explain this behavior is the effect of changes in the composition of households, especially with regard to the decrease in the number of residents. Thus, we have the following scenario: the people in the household are aging and, along with the income of these people increasing, there are fewer people in the households. This combination of increasing income with age and decreasing number of people in the household causes per capita income to increase in households with older heads of household (Maia & Sakamoto, 2014).

However, income does not explain the whole relationship between consumption and demographic dynamics. The consequences of changes in the structure and composition of households can be factors that directly influence the level of household consumption, without necessarily going through the income factor. As an illustration of this hypothesis, it can be said that households have fewer and fewer people to share common energy consumption goods, such as a refrigerator, stove (electric box), electric shower, etc.; an aspect that represents the scale effect of this relationship, thus increasing per capita consumption.

Consequently, it can be said that as households age, they tend to have fewer people per household and to present household arrangements without children, increasing the effect of economies of scale on consumption, as pointed out by Menz & Welsch (2012). In addition, there must be a higher level of income, which should also contribute to increased consumption. This means that there are confounding factors related to self-correlation that act on this relationship.

Therefore, it is imperative to note that the analysis of these results must be properly weighed by these effects that income and household composition cause on the consumption growth, in addition to changing the age structure, which is the main objective of analysis in this work.

3.1. The consumption of household arrangements

The descriptive analysis of household electricity consumption per capita by type of family arrangement allows us to suppose that there are differences in the level of consumption that can be explained in addition to the increase in household income. For this, the SCR described in the previous step will also be calculated according to the types of household arrangement that will be created from the relationship reported in the *POF*. Thus, the arrangements considered for the purposes of this analysis were:

- Single person;
- Couple without children;
- Couple with children (nuclear);
- Female single; and
- Others.

The choice of these arrangements is justified because it represents the majority of Brazilian families (Alves *et al*., 2010). Thus, it can be seen (as shown in Figure 2) that the largest SCR found were for single-person households and couples without children, which confirms (for the Brazilian case) what the literature had discussed. Single-person households had an average per capita electricity consumption of 116.09 kWh, while those formed by couples without children had 70.09 kWh.

The one-person arrangement stands out from the others because the role of the scale effect is more evident in the households with this arrangement, meaning that there are more consumer goods serving only one person. In addition, there may be associated factors acting on single-person households, such as higher income and the age structure of this type of household. Then, the household arrangement that has the second highest level of energy consumption per capita is that of a couple without children. These two types of arrangements that have the largest SCR (single person and childless couples) are precisely the arrangements with the least number of people and the absence of children. The arrangement with the lowest SCR was the nuclear: about 45.46 kWh. According to the data, a person in a single-person household consumes more than twice as much as a person in a nuclear household.

Thus, the household arrangements that have the highest levels of per capita consumption are those with the highest growth rate in relation to the others in the country. According to Alves & Cavenagui (2012), these two types of family arran-

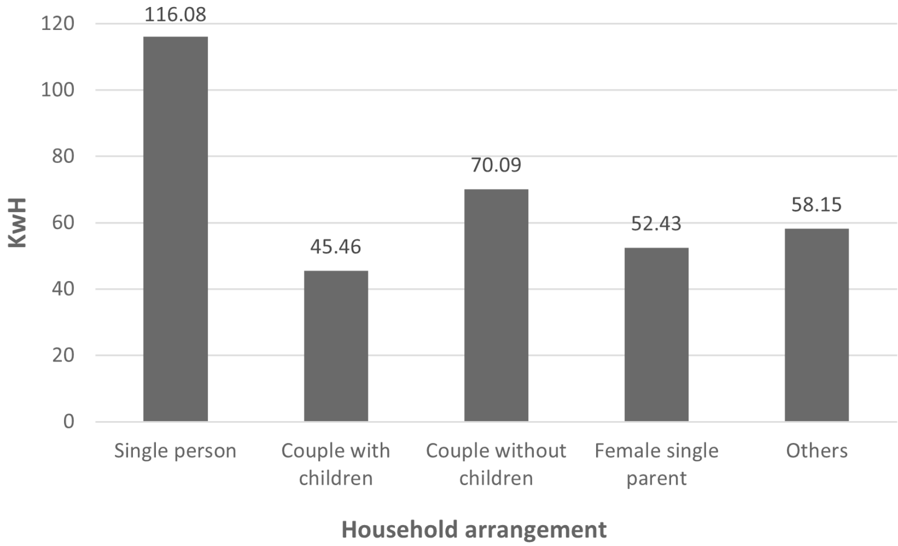

FIGURE 2 – SCR by household arrangement in Brazil – 2009.
SOURCE: IBGE (2008), Microdata from the *POF* 2008/2009.

gements increased their participation in Brazil by 20% and 54% between 1980 and 2010, respectively. The arrangement that has the lowest SCR (couple with children) is precisely the one that presents the greatest loss of relative participation in Brazilian households, going from 65% of Brazilian households in 1980 to 52.5% in 2010, a drop in the order of 24% (Alves & Cavenaghi, 2012).

In addition to the aging of the population itself, this path towards a new composition of Brazilian households in terms of their composition and family arrangements will probably continue in the coming decades and with an irreversible character. Thus, the increase in the participation of the arrangements that consume more electricity and the decrease in those that consume the least will tend toward a higher level of consumption in the future by Brazilian households. This is a result that deserves to be highlighted in this research and that, to a certain extent, deconstructs the common sense argument that smaller families would help reduce the impact of population on the environment and justify birth control policies.

4. The impact of age structure on total energy consumption

As already mentioned, the literature points out that there would also be an aging trend among heads Brazilian household heads as a reflection of aging of the population. Therefore, one of the options for verifying the impact of the Brazilian demographic transition on energy consumption would be to assess a standard age structure that contains a higher proportion of older household heads than was observed in 2009. However, for this it would be necessary to obtain projections of the Brazilian population considering the age distribution of household heads. Given the methodological difficulty of obtaining projections at this level of detail, it was decided to develop an inverse analysis in which the consumption levels by age and total obtained for 2009 were applied to a known age distribution of household heads.

Therefore, we used the age distribution of households obtained in the 1970 Demographic Census (2015), because we understand that this was a context in which the demographic transition process had its first more evident reflexes in the age structure of the country's population, but still maintained a predominantly young country. Figure 3 confirms this assumption, as it illustrates the age distribution of the total Brazilian population from the 1970 and 2010 Demographic Censuses.

This fact, associated with that presented in Figure 4, corroborates the transition of the age structure of the households. This means that there was been a significant aging of the age structure of the households, as identified in this study by the aging of the household heads.

Thus, the consumption rates obtained for the year 2009 were standardized by having defined the standard age structure of households by the age of the head of households. Having obtained the Specific Consumption Rates by "Age of the Household" and the gross electricity consumption per capita (GCR), we sought to verify how the GCR of Brazil in 2009 would behave if households had the age distribution of households in 1970. In other words, what would be the level of energy consumption of Brazilian households if the household structure behaved as if it were still in an early period of the demographic transition.

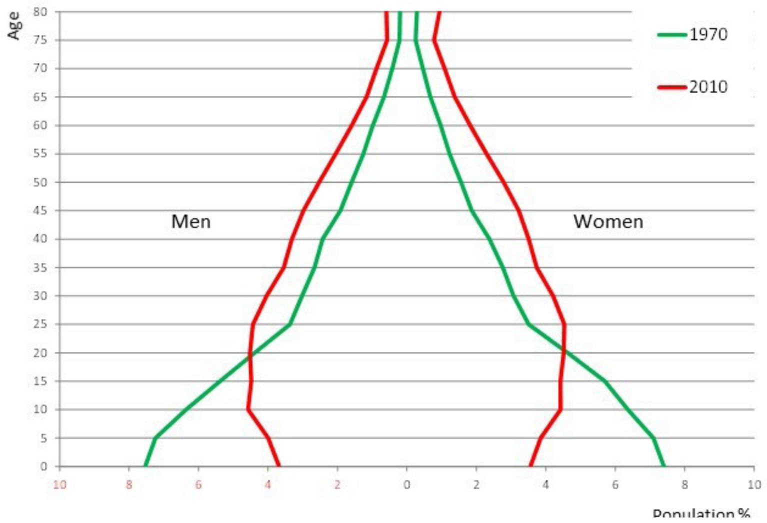

FIGURE 3 – Age structure and gender of the Brazilian population, 1970 and 2010.
SOURCE: IBGE (2010), Demographic censuses of 1970 (2015) and 2010.

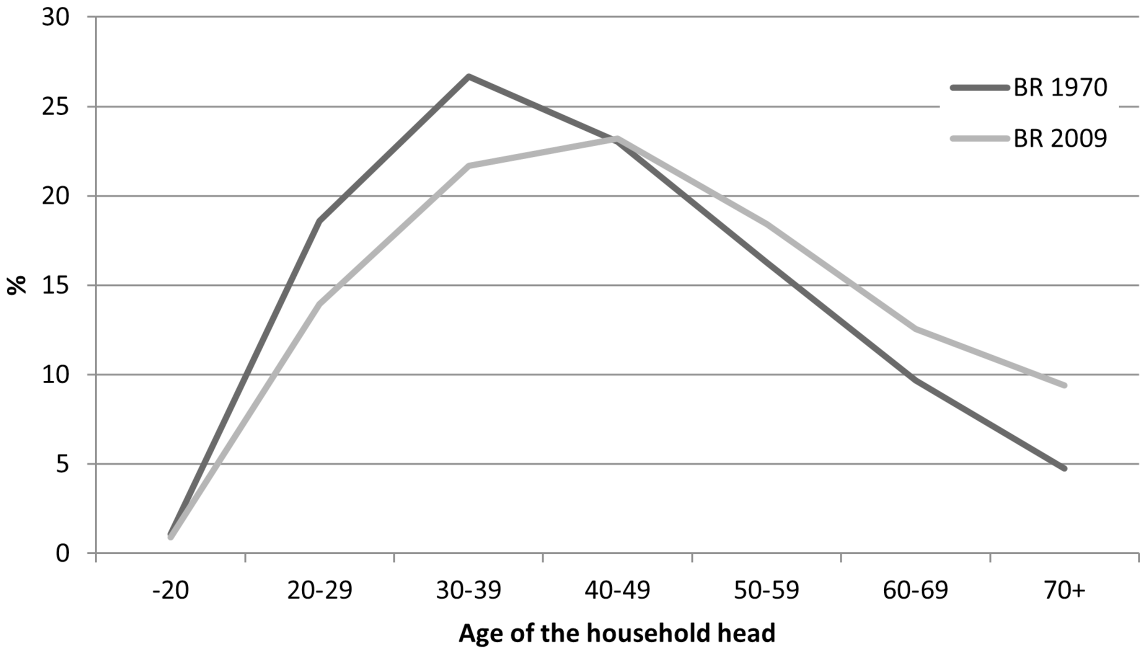

FIGURE 4 – Household composition by age of the household head, Brazil, 1970 and 2009.
SOURCE: IBGE (2008), Demographic Census 1970 (2015) and Household Budget Survey 2008/2009.

Thus, the standardization formulation adopted by the work is presented below:

$$GCR_{s.h} = \frac{\sum_x SCR_x \cdot {}_nHou_{x,s}}{\sum_n Hou_{x,s}}$$

In which:
$GCR_{s.h}$ = Gross consumption rate of household electricity per capita standardized by composition of households by life cycle stages;
${}_xSCR_x$ = Specific consumption rate of household electricity per capita between ages x and x+n, where these ages refer to the age of the household head;
${}_nHou_{x,s}$ = Number or proportion of households age x and x+n of the structure adopted as standard, where this age refers to the age of the household head;

The GCR of Brazil in 2009 was 59.5 kWh and Table 1 presents the results of the standardization of the GCR obtained from the *POF* data of 2009 in the age structure of Brazilian households in the year 1970. Therefore, the result achieved indicates that we would have a GCR of 56.9 kWh if the SCR of 2009 were experienced by a population that had the age structure of household heads in Brazil in 1970. A difference of 2.6 kWh less only due to the change in age structure.

TABLE 1 – Gross Consumption Rate standardized by age of the household head (direct method), Brazil (2009) and Age Structure (1970).

Age groups of heads of households	A SCR Brazil (2009)	B % of households Brazil (1970)	A * B
-20	45.5	1.1%	0.5
20 to 29	48.0	18.6%	8.9
30 to 39	49.4	26.7%	13.2
40 to 49	56.9	23.0%	13.1
50 to 59	66.4	16.2%	10.8
60 to 69	69.6	9.7%	6.7
70+	78.0	4.7%	3.7
GCR BRAZIL 2009	59.5	GCR BR 09 p/ BR 1970	56.9

SOURCE: IBGE (2008), Demographic census 1970 (2015) and Household Budget Survey 2008/2009.

The difference obtained between the GCR may seem small at first glance, but it is important to remember that GCR is a per capita measure and when generalizing this difference (which is individual) the entire Brazilian population, it is certainly a relevant difference in energy consumption levels for the Brazilian electrical system. Thus, if we multiply this difference by the total Brazilian population, we would obtain a difference of 520 thousand MWh. Therefore, if the Brazilian population identified in 2009 had the same pattern of domestic energy consumption, but had the age structure it had in 1970, this would be the value that Brazil would have stopped consuming if it had not gone through the demographic transition.

To have a comparison parameter, the electricity savings obtained by imposing daylight saving time between 2012 and 2013 was on the order of 2,477 MWh (ONS, 2013). If this same energy savings had occurred every summer between 1970 and 2009, the result would have been an accumulation of electricity savings that would represent five times less than the increase in energy consumption in Brazilian households due to aging over the same period.

5. The future of consumption and population: exploratory notes

According to data from the National Household Sample Survey (*PNAD*), there has been an increase in the percentage of almost all durable consumer goods present in Brazilian households with emphasis on the washing machine, which was in 33.64% of households in 2001 and increased to over 50% in 2011. Furthermore, refrigerators went from 85.12% to 95.75% in the same period. Also according to *PNAD* data, the percentage of households with internet access increased from 13.7 to 36.5% between 2005 and 2011. The increase in the economy with the inclusion of a portion of the population that had previously been marginalized from the consumer market will naturally bring higher energy expenditures and increase its intensity.

The National Agency for Electrical Energy - *ANEEL* (2008) corroborates the hypothesis of an increase in the intensity of electricity consumption in Brazil. According to the agency's publication, the residential electricity consumption in Brazil has grown at a much faster pace in recent years than population growth. Data from the (Statistical Yearbook of Electric Energy) Anuário Estatístico de Energia Elétrica (EPE, 2013) show that residential energy consumption in Brazil grew by 5.1% between the years 2011 and 2012. Thus, the level of residential electricity consumption in Brazil should continue to increase in the future due to two associated aspects: the increase in SCR and the aging process of the population. But what we seek to highlight with the analysis proposed here is that the transition component of the population/household age structure is usually not taken into account in the analyzes.

Studies on consumption from a demographic perspective are increasing in the international and national literature, proving that there are several factors of demographic dynamics that have great influence onlevel and pattern of consumption of a population. However, more research is still needed to consolidate the population-consumption-environment theme in the case of Brazil. The debate on consumption through a demographic perspective is proving increasingly relevant to discuss in a more systematic and consistentway a "consumption demography".

The scale of analysis, the consumption units or metrics, the demographic characterization of the research unit, the data source and analysis techniques were some aspects which still require much deeper analyzes to evaluate its various interfaces. Thus, advanced studies that explore and diversify the approaches to these terms are of great relevance and deserve greater efforts.

Regarding the results of this article, it is highlighted that the age structure of households has a positive impact on the aggregate consumption of electricity. But it would be worth exploring the impact of changes in household arrangements in more detail, as there were important differences in per capita electricity consumption in single-family households and couples without children. These are the arrangements with the lowest number of residents who do not have children and that have the highest per capita income, which are important characteristics for increasing in per capita household consumption. In a preliminary way, it is observed that the household arrangements that present higher levels of consumption are those that present significant growth in proportional terms.

Regarding the limitations of data and results, there are the effects of income and family composition on increased consumption, in addition to the age structure. As pointed out by Silva et al. (2012), these variables self-correlated in the processes of demographic transitions. Thus, as a suggestion for future work, we hope to use techniques that isolate the effects of these confounding variables, as proposed by Del Guercio (2015), for example. In other words, do households that have the same income level, but have different ages of the household head and/or different arrangements also have different consumption levels?

In addition to this discussion, the results of this research give rise to the need for greater attention to policies and programs aimed at promoting energy savings, as it is also necessary to compensate for the effects of the future aging of the population and changes in household arrangements in order to have a real economy. Thus, new products must be increasingly more efficient and economical in order to achieve these effective gains in terms of energy savings, and there must be a rate of products replacement at a speed capable of overcoming the aging process, because it would be useless to have less energy-intensive products in Brazilian households if they are not being replaced.

The results of the article provoke other questions that will not be fully discussed in this work due to its complexity, but that are worth mentioning. Criticisms of the culture of consumption and its most extreme form, consumerism and the individualistic character increasingly present in the mode of consumption to the detriment of the sharing goods and services are reflections that the results impose on us and should be the target of special attention among public agents and be increasingly present in the population's awareness process.

As a conclusion, it is necessary to reiterate that the results of this research do not deny that there is a contribution of the volume and the rate of population growth to environmental aspects. However, what this research intends to show is that there is a hegemonic Malthusian understanding that obscures the importance of other demographic factors of equal or greater importance in impacting the environment.

If, on the one hand, demographers are no longer concerned with the need to demystify the Malthusian consensus, on the other, there is a repeated rescue of "population size" as the main villain of global environmental changes not only by common sense, but also of other fields of knowledge.

Finally, we conclude that, contrary to what would be expected, reducing the pace of population growth or even having negative population growth rates could lead to increased levels of household electricity consumption. In other words, fewer people are not always better; nor are more people always worse. However, it is important to note that this tends to hold true until the population fertility and mortality levels stabilize. When this happens, there are no more changes in the age structure of the population and possible variations in the population's consumption levels become predominantly effects of the increase or decrease in the number of people, energy efficiency and/or even variation in the composition of this population by other characteristics besides age. Therefore, to infer that smaller families are beneficial to the environment without considering other demographic aspects is nothing more than reductionism.

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