The energy consumption and the CO_2 emissions in different income class in Sao Paulo state and rest of Brazil: The IRIO approach

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Abstract

The main propose of this study is to analyze the consumption of different types of energies and the level of CO_{2-eq} emission per different income class in Sao Paulo State and the Rest of Brazil. We distinguish household in twelve classes of income for year of 2008, with estimated levels of energy consumption and emissions through the construction of interregional input–output model reconciliation of the National Energy Balance. We found that classes with higher income tend to consume more of the sectors that have the highest rate of efficiency of energy and carbon emission. The Household in Sao Paulo state have the major impact in the energy demand and CO2-eq emission. But the energy demand and the CO2-eq emissions by monetary unit are biggest in the smaller income class.

Keywords: CO_2 Emissions. Input-Output model. Household consumption. Energy use.

JEL: C67, D57, Q56

1 Introduction

The recent increase in the economy activity have been come with the increasing pressure on the environment. In contraste, It has been improved the standard of living and welfare. In the last few decades, the world has given clear signs that its capacity to absorb residues is running out. These include industrial waste, like greenhouse gases emissions.

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The policy makers have been facing a challenging that it is to understand the fragile linkage between the economic activity, the energy consumption and the environmental impact. (Alcántara and Padilla, 2003; Llop and Pié, 2008; Liu et al., 2009)

The importance of consumers and their consumption patterns have attracted increasing attention about the impact on energy consumption and emissions. The total energy requirement increases with the income level such as many studies have been showed and the urban household consume more energy than rural area. This phenomenon occurs because of the increase of accessibility to goods and services more industrialized for the household with highest income. The urbanization imply that most of resources are consumed in cities for industrial activities, commercial and transport. Their consequences are the positive correlation between income growth and increased emissions. The urban environment pressure rises can shift from a local problem to a global problem. (Cohen et al., 2005; Behrens, 1986; Kerkhof et al., 2009; Lenzen, 1998; Lenzen et al., 2004; Liu et al., 2009; Vringer and Blok, 1995; Bin and Dowlatabadi, 2005).

Household are more familiar with the use of the direct energy, and most of the discussion focus in this kind of energy requirement. The household direct energy use are specially for cooking, transport, electronic appliances but they do not even realize that use indirect energy embodied in the consume of goods and services. These consist in the main kind of energy consumed and represent an important proportion of all energy consumed. The direct energy requirement is the most import for the lowest income classes and food is the most important indirect energy requirement for most income classes.(Vringer and Blok, 1995; Liu et al., 2009; De Martino Jannuzzi, 1989; Biesiot and Noorman, 1999; Park and Heo, 2007; Feng et al., 2011; Munksgaard et al., 2001, 2005; Rosas et al., 2010)

The direct energy represents a small part of the income. Household consume more energy indirectly through the goods and services than directly energy per itself. While the direct energy tend to saturation point, the indirect energy showed rapid rise with increasing income. The energy intensity decrease when the household income increase due to the fact that the proportion of the expenditure on direct energy decrease. (Herendeen and Tanaka, 1976; Vringer and Blok, 1995; Golley and Meng, 2012).

The direct emission is proportionally small when compared with the total emissions. they represent only 6%. The main emissions are attributable to purchases of goods and services to support the modern lifestyle. The consequences are that the total emission per capita declines over the income range. (Lenzen, 1998). The poorest people are more energy intensive and therefore more carbon intensive in their total expenditure patterns.

The main purpose of this paper is to identify the relation between household expenditure, energy requirement and GHG emissions for 12 income classes. Measure the total, indirect and direct energy requirement. The relation between Sao Paulo State and the Rest of Brazil, in terms of energy requirement by different sets of consumption.

2 Literature Review

One the first work in Brazil was Behrens (1984) that showed if it was implemented a more egalitarian income, the total energy consumption would increase, specially direct energy and substituted by more efficiently burned fuels. Behrens (1986) and De Martino Jannuzzi (1989) emphasized the differences in the energy quality requirements between urban and rural household according to their levels of expenditure. Cohen et al. (2005) and Lenzen et al. (2006) showed the great importance of the mobility in the total energy demand, especially in the cities as have been shown by Lenzen et al. (2004).

Analyzing the impact od the final demanda for Australian energy demand and GHG emissions, Lenzen (1998) concluded that Household are main causative of these, specially by purchase de goods and services and the increase in emissions was strongly related to income growth.

Kerkhof et al. (2009) confirmed, to the Netherland, that environmental impact are positively correlated to household income. The impacts are related to mix consumption of necessities and luxuries goods. However the necessities are more important in GHG emissions than luxuries and consequently, the correlation are less than proportional with increasing expenditure. Vringer and Blok (1995) also confirmed the positive correlation between energy consumption and household income and the main consumption categories were transport, education and leisure.

Munksgaard et al. (2000) showed, to Denmark, that household consumption was the main force for the growth GHG emissions. But they emphasized that the improvement in the energy intensity was very important to reduce the consequences of the private consumption. Given the importance of food sector, it will be necessary providing incentives for energy saving in this sector, the same sector found by Pachauri and Spreng (2002) to India.

Liu et al. (2009) confirmed, for Chinese economy, that indirect energy is the main source of energy consumption, a much more than direct and the urban area consume more than rural area in both sources. Feng et al. (2011), using CLA, found similar results for energy and emissions and Yuan et al. (2010) showed the importance of exports in energy demand. To Republic of Korea, Park and Heo (2007) argue that higher energy prices for household could be a strong measured for energy conservation.

3 Methodology

The input-output model represents the economic activities' interdependence from a country, region or state and allows examine the relations between differents economic sectors (table 1). In the late of 1960, the concern about how economics activities and environmental interrelate led to development the environmental models. the main contributers were Isard et al. (1968); Daly (1968); Ayres and Kneese (1969); Leontief (1970); Cumberland and Korbach (1973), for energy models were Bullard III and Herendeen (1975); Herendeen and Tanaka (1976). There are many application to Brazil, we can cite Machado et al. (2001); Guilhoto et al. (2002); Hilgemberg and Guilhoto (2006); Imori and Guilhoto (2007); Guilhoto et al. (2007); Imori and Guilhoto (2008); Lopes and Guilhoto (2013).

Table 1. Flow data for two–region interregional input–output matrix

Selling \ Buying		Region r 1	2	3	Region s 1	2	3	Final Demand r	s	Total Output
Region r	1	z_{11}^{rr}	z_{12}^{rr}	z_{13}^{rr}	z_{11}^{rs}	z_{12}^{rs}	z_{13}^{rs}	f_1^{rr}	f_1^{rs}	x_1^r
	2	z_{21}^{rr}	z_{22}^{rr}	z_{23}^{rr}	z_{21}^{rs}	z_{22}^{rs}	z_{23}^{rs}	f_2^{rr}	f_2^{rs}	x_2^r
	3	z_{31}^{rr}	z_{32}^{rr}	z_{33}^{rr}	z_{31}^{rs}	z_{32}^{rs}	z_{33}^{rs}	f_3^{rr}	f_3^{rs}	x_3^r
Region s	1	z_{11}^{sr}	z_{12}^{sr}	z_{13}^{sr}	z_{11}^{ss}	z_{12}^{ss}	z_{13}^{ss}	f_1^{sr}	f_1^{ss}	x_1^s
	2	z_{21}^{sr}	z_{22}^{sr}	z_{23}^{sr}	z_{21}^{ss}	z_{22}^{ss}	z_{23}^{ss}	f_2^{sr}	f_2^{ss}	x_2^s
	3	z_{31}^{sr}	z_{32}^{sr}	z_{33}^{sr}	z_{31}^{ss}	z_{32}^{ss}	z_{33}^{ss}	f_3^{sr}	f_3^{ss}	x_3^s
Imports		m_1^r	m_2^r	m_3^r	m_1^s	m_2^s	m_3^s	m_f^r	m_f^s	
Value Added		va_1^r	va_2^r	va_3^r	va_1^s	va_2^s	va_3^s			
Total Output		x_1^r	x_2^r	x_3^r	x_1^s	x_2^s	x_3^s	x_f^r	x_f^s	
Energy Consum.		e_1^{rr}	e_2^{rr}	e_3^{rr}	e_1^{rs}	e_2^{rs}	e_3^{rs}	e_f^{rr}	e_f^{rs}	
		e_1^{sr}	e_2^{sr}	e_3^{sr}	e_1^{ss}	e_2^{ss}	e_3^{ss}	e_f^{sr}	e_f^{ss}	
GHG emissions		g_1^r	g_2^r	g_3^r	g_1^s	g_2^s	g_3^s	g_f^r	g_f^s	

Source: Miller and Blair (2009); Wiedmann et al. (2006)

Where:

z_{ij}^{lk} intermediate flow from sector i in region l to sector j in region k
f_i^{lk} total final demand from sector i in region l to region k
x_i^l total output of sector i in region l
m_j^k imports by sector j in region k
m_f^k imports by final demand f in region k
va_j^k value add by sector j in region k
x_f^k total final demand f in region k
e_j^{lk} total energy demand from region l by sector j in region k
e_f^{lk} total energy demand from region l by final demand f in region k
g_j^k GHG emissions by sector j in region k

The system of equation 1 shows the basic relation in the input-output matrix. The equation 1a represent the mathematic relation of the table 1. We can use substitution to represent the system in terms of technical coefficient, equation 1b. After matricial manipulation, we can show the dependence between the gross output and final demand. (see eq. 1c)

$$\mathbf{X} = \mathbf{Zi} + \mathbf{F} \tag{1a}$$
$$\mathbf{X} = \mathbf{AX} + \mathbf{F} \tag{1b}$$
$$\mathbf{X} = \mathbf{BF} \tag{1c}$$

$$\mathbf{A} = \mathbf{Z}\widehat{\mathbf{X}}^{-1}$$
$$\mathbf{B} = (\mathbf{I} - \mathbf{A})^{-1}$$

where:

A technical coefficient matrix;
X total output vector

$\mathbf{F}$ final demand vector
$\mathbf{Z}$ intermediate flow matrix
$\mathbf{B}$ Leontief inverse matrix
$\mathbf{I}$ identity matrix

The energy coefficient is calculated dividing the total energy use by gross output from each industry (eq. 2). We have two types of energy coefficient vector, one is the energy produced and used in the same region (eq. 2a) and other is the energy produced in one region and used in another (eq. 2b).

$$\mathbf{CE}^{ll} = \mathbf{E}^{ll}\widehat{\mathbf{X}}^{-1} \tag{2a}$$
$$\mathbf{CE}^{lk} = \mathbf{E}^{lk}\widehat{\mathbf{X}}^{-1} \tag{2b}$$

where:
$\mathbf{E}^{ll}$ energy consumption in region l produced in region l
$\mathbf{E}^{lk}$ energy consumption in region k produced in region l
$\mathbf{CE}^{ll}$ energy consumption coefficient in region l produced in region l
$\mathbf{CE}^{lk}$ energy consumption coefficient in region k produced in region l

For the energy direct use by final demand, we have the same logic that was showed before. Equations 3 represent the share of direct energy use by final demand. Equation 3a represents the use the energy produced inside and the equation 3b represent the use the energy produced outside.

$$\mathbf{CE}_f^{ll} = \mathbf{E}_f^{ll}(\mathbf{F}^l/\mathbf{F}^l\mathbf{i}) \tag{3a}$$
$$\mathbf{CE}_f^{lk} = \mathbf{E}_f^{lk}(\mathbf{F}^l/\mathbf{F}^l\mathbf{i}) \tag{3b}$$

where:
$\mathbf{E}_f^{ll}$ energy consumption by final demand in region l produced in region l
$\mathbf{E}_f^{lk}$ energy consumption by final demand in region k produced in region l
$\mathbf{CE}_f^{ll}$ energy consumption coefficient by final demand in region l produced in region l
$\mathbf{CE}_f^{lk}$ energy consumption coefficient by final demand in region k produced in region l
$\mathbf{F}_f^l$ household final demand in region l

The emission coefficient (eq. 4) are similar with the energy coefficient but we don't have distinguishing between inside and outside. In 4a, we have the emissions related to production system and equation 4b represents the direct emissions coefficient by final demand.

$$\mathbf{CG} = \mathbf{G}\widehat{\mathbf{X}}^{-1} \tag{4a}$$
$$\mathbf{CG}_f^l = \mathbf{G}_f^l(\mathbf{F}^l/\mathbf{F}^l\mathbf{i}) \tag{4b}$$

where:

$\mathbf{CG}$ GHG emissions coefficient

$\mathbf{G}$ GHG emissions

$\mathbf{CG}_f^l$ GHG emissions coefficient by final demand in region l

$\mathbf{G}_f^l$ GHG emissions by final demand in region l

Combining the equation 1a with 3a and 3b, and post-multiplying equation 4a and 4b by household final demand, we can measure the total energy required by this household. If we use a specific class of income, we can determined the total energy required for such class. (eq. 5)

$$\mathbf{TE^{in}} = \mathbf{CE}^{ll}\mathbf{BF}^{l} \tag{5a}$$
$$\mathbf{TE^{out}} = \mathbf{CE}^{lk}\mathbf{BF}^{l} \tag{5b}$$
$$\mathbf{TE_f^{in}} = \mathbf{CE}_f^{ll}\mathbf{F}^{l} \tag{5c}$$
$$\mathbf{TE_f^{out}} = \mathbf{CE}_f^{lk}\mathbf{F}^{l} \tag{5d}$$

$$\mathbf{TE^{in}} = \begin{vmatrix} TE_{ll}^{in} & TE_{lk}^{in} \\ TE_{kl}^{in} & TE_{kk}^{in} \end{vmatrix}$$

$$\mathbf{TE^{out}} = \begin{vmatrix} TE_{kl}^{out} & TE_{klk}^{out} \\ TE_{lkl}^{out} & TE_{lk}^{out} \end{vmatrix}$$

In equation 5a we have two kinds of results. TE_{ll}^{in} and TE_{kk}^{in} that represents the energy produced in the region and used inside, in the production process, and TE_{kl}^{in} and TE_{lk}^{in} that represents the energy produced in the region and used in the inputs that will be send to another region. this represent the energy embodied.

In equation 5b we have others two kinds of results. TE_{kl}^{out} and TE_{lk}^{out} that represents the energy produced in the region and send for to be used in another region, and TE_{lkl}^{out} and TE_{klk}^{out} that represents the energy produced in the region that will be send for to be used in another region to produced inputs that will be send to first region. this also represent the energy embodied.

In the equation 6 we have the total energy required by specific class of income in region l. The equation 6a represents the indirect energy required in the region l and in equation 6b the indirect energy required in the region k to support this such class of income. The equation 6c and 6d represents the direct energy required by such income class. 6c is energy from region l and 6d from region k.

$$\mathbf{TE^{l}} = \mathbf{TE}_{ll}^{in} + \mathbf{TE}_{lkl}^{out*} + \mathbf{TE}_{lk}^{in*} + \mathbf{TE}_{lk}^{out} \tag{6a}$$
$$\mathbf{TE^{k}} = \mathbf{TE}_{kk}^{in} + \mathbf{TE}_{klk}^{out} + \mathbf{TE}_{kl}^{in} + \mathbf{TE}_{kl}^{out} \tag{6b}$$
$$\mathbf{TE_f^{in}} = \mathbf{CE}_f^{ll}\mathbf{F}^{l} \tag{6c}$$
$$\mathbf{TE_f^{out}} = \mathbf{CE}_f^{lk}\mathbf{F}^{l} \tag{6d}$$

To determine the emissions, we use the equation 7. In equation 7a, we have calculated the emissions associated to production of goods and services and equation 7b the emissions associated with direct use of energy by household.

$$\mathbf{TG} = \mathbf{CG}.\mathbf{B}.\mathbf{F}^{l} \tag{7a}$$

$$\mathbf{TG}_{f} = \mathbf{CG}^{l}_{f}.\mathbf{F}^{l} \tag{7b}$$

where:

k means 1 to energy and 2 to emissions
q_k^{ind} is a vector of industrial multipliers
I is the identity matrix
A is the matrix of technical coefficients

3.1 Data preparation

The analysis period comprised the year 2008. The input-output matrix is used as a basis for this study and it have been estimated using Guilhoto and Sesso (2005)'s methodology.

Energy data was gathered from the 2012 National Energy Balance, elaborated by the Ministry of Mining and Energy EPE (2013) and Energy balance of the state of Sao Paulo SESP (2013). This statistic cover only 22 sectors. To combine this data with input-output data, where there are 56 sectors, was used Montoya et al. (2013)'s methodology. The source of household expenditure was used the consumer expenditures survey by IBGE (2010)

In this paper we have considered three types of GHG, CO_2, CH_4 and N_2O. We have used the emission coefficients from IPCC (2006) and for sugar cane bagasse and ethanol was used from E&E (2000) that were further converted into CO_{2-eq} using the converter factors estimated by UNFCCC (1995)

4 Results and discussion

Comparing the income, energy and emission concentration it's possible to see that energy and emissions are less concentrated than income. (see Tab. 2). These results are according with had been already showed by Cohen et al. (2005) and Schaeffer et al. (2003). The desconcentration observed in energy is the social programs impact like social tariff. This ensures ease of access to energy for lowest classes. The emissions in São Paulo for the lowest class is related to the public transportation dependence, that use intensively diesel fuel, and large distance to travel to work.

Table shows the Energy Elasticity and emissions elasticity. The elasticities have been measured according to Vringer and Blok (1995). The results show positive correlation between income – energy and energy – emissions (see Tab. 3). The energy elasticity is less than proportional to income. Suggesting levels off in long term. The emissions elasticity indicated that the increase is nearly to the proportional to energy. These are clearly that emissions increase proportionally to the energy consumption.

Table 2. Gini index for income energy and emissions

	SP	RBR
Income	0.464	0.531
Energy	0.321	0.351
Emissions	0.306	0.365

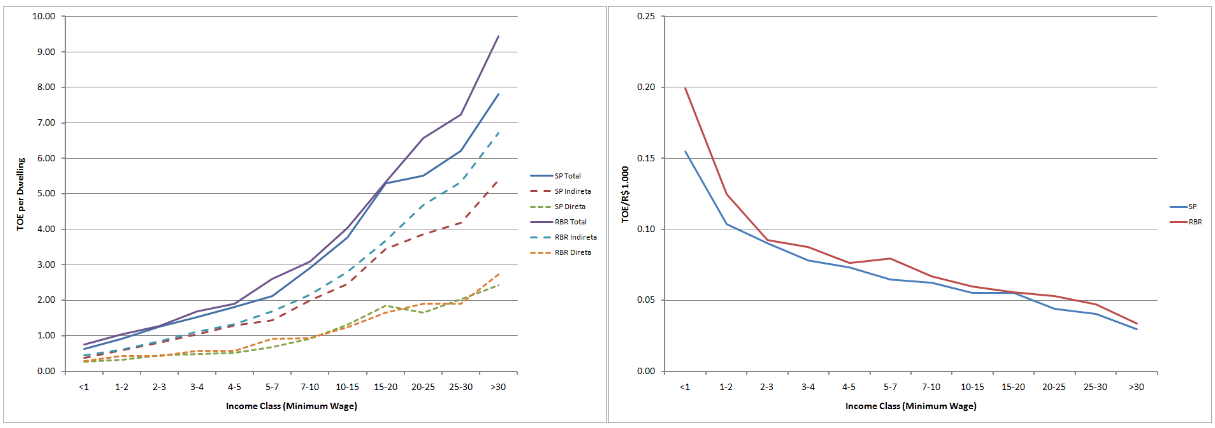
Table 3. Add caption

Elasticity	SP	RBR
Energy-Income	0.65	0.64
Emissions-Income	0.64	0.66
Emissions-Energy	0.99	1.03

4.1 Energy

The average consumption per dwelling shows that when the income increases, the energy consumption rises (Fig. 1a). The highest class of consumption is more than twelve times greater than the lowest class in total consumption. This value is smaller than found out by Cohen et al. (2005) that was 18 times. For indirect energy, more than fourteen times and more than nine times in direct energy, in both regions. It's possible to check that the lowest class is narrow to the average than the past. While in São Paulo state the Average class is 3.9 times greater than lowest, in the Rest of Brazil it is more than 2.7 times, in contrast to Cohen et al. (2005) with 5.3.

The direct energy consumption are more important in the lower classes. This situation can be explained by limited access to goods and services faced the lowest classes, in contrast with the highest classes. The share in lowest class is 42% for São Paulo and 39% for Rest of Brazil, this shares falls to 31% and 29% respectively for the highest class, but they exhibit the same average, 33%. When we compare with oldest results, they show the improvement in the life style. In 1970 decade, Behrens (1986) showed that direct energy was about 78%. This results are strong evidence of the progress of the lifestyle in Brazil.



(a) Average energy consumption

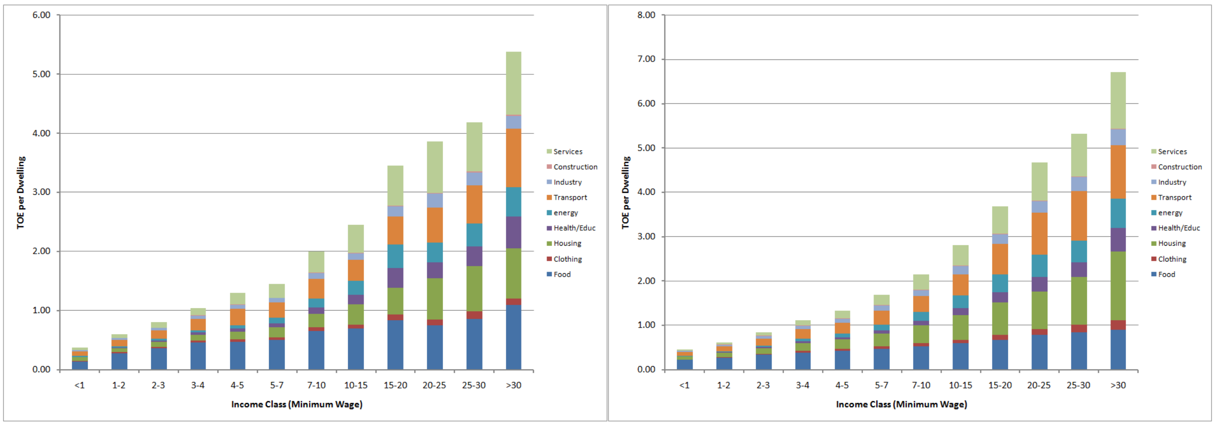
(b) Energy intensity

Figure 1. Average energy consumption and intensity by income classes

The intensities by income class shows that the lowest class are more energy intensive than the highest classes (Fig. 1b). This negative correlation had been already observed by Behrens (1986). The explain for this relation is because the increase in the price of goods and services are greater than energy requirements itself. The lowest class, in Rest of Brazil, needs 28% more energy than the same class in São Paulo state. In the highest class this share falls to 14%. On the average, the Rest of Brazil needs 20% more energy per Real than São Paulo. This results show that São Paulo state is more energy efficient.

Energy consumption by categories shows that food is most import for all categories for São Paulo and until 15 minimum wages for Rest of Brazil (Fig. 2) but in decreasing rate. The share begin with 38% and 48% for Sao Paulo and Rest of Brazil, respectively, and, for the highest income class, the share falls to 20% and 13% and the importance falls to third and fourth. This can be explained because food has a saturation point and the difference between São Paulo and the Rest of Brazil is because in São Paulo there are more consumption of the processed food.

In São Paulo, the services are the second most important sector for the six highest income classes with about 20%. For classes under 7 minimum wage, the transport become the second, with 19% in average. This is consequences of urbanization, for highest classes, and great dependence of public transportation for lowest classes. For the Rest of Brazil, similar to São Paulo, the transport is the second most important sector for the same classes.



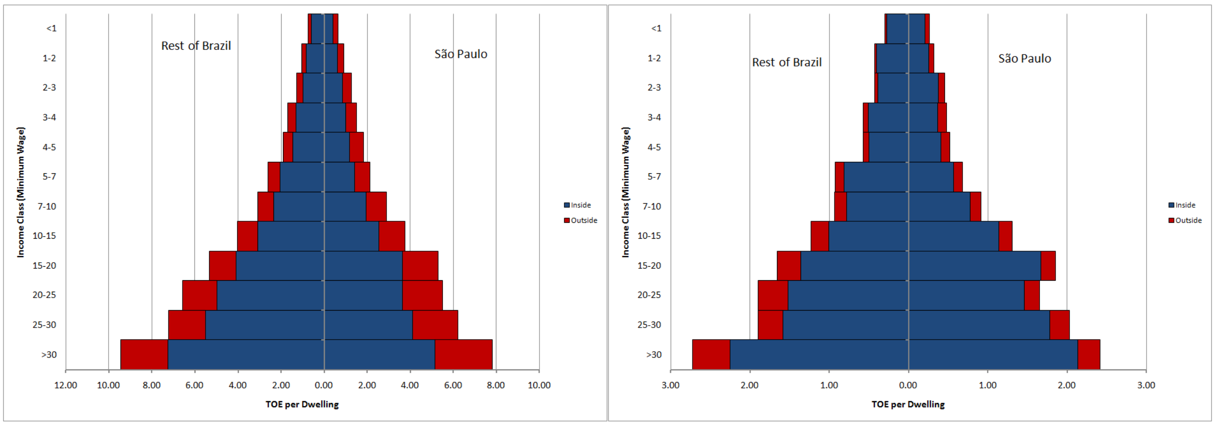
(a) São Paulo State

(b) Rest of Brazil

Figure 2. Average sectoral energy consumption by income class

The structure of energy consumption for classes with income equal or over 20 minimum wages change. While the classes under 20 the three sectors most important are Food, Housing and Transport, for the highest classes, they change food for services. After food saturation point, the household can drive your expenditure to services, like education, medical care, recreation and communication. The health care and education increase with the income in both regions. In São Paulo begin with 1.6% and goes to 10% and in the Rest of Brazil 2.3% to 7.8%. The energy sector has the same characteristic, 4.9% to 9.2% to São Paulo and 3.1% to 9.8% to Rest of Brazil. These increase can be associated to purchase of electronics appliances and durable goods like personal computers, wash machines, and so on. Clothing, Construction and Industry are relatively constante in both regions.

Sao Paulo is one of the most important state in energy supply. Yours Gross domestic supply represents about 26% from national supply, the participation in the final energy consumption is the same. When we compare the dependence of total energy (fig. 3a), the Sao Paulo use about 33% from outside energy and the rest of Brazil use about 23%.



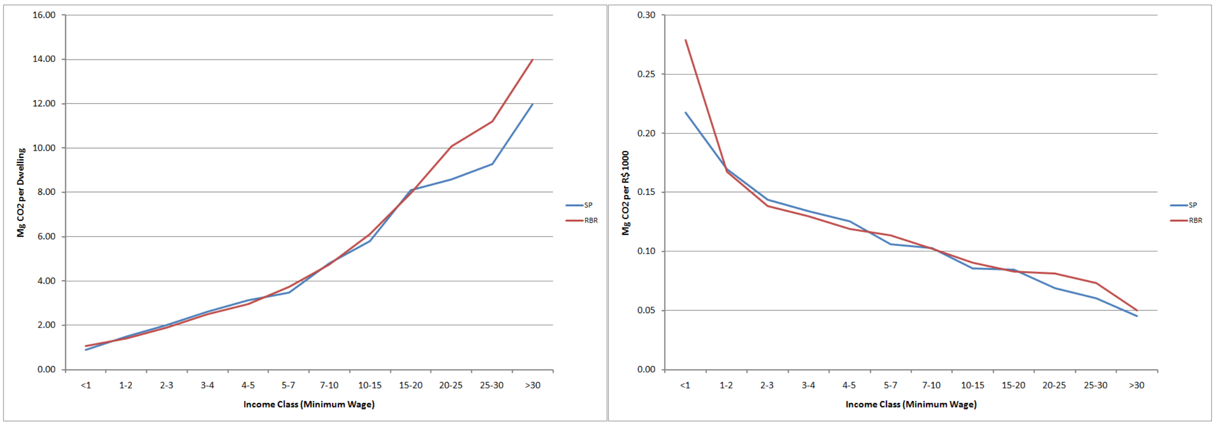
(a) Average total energy consumption (b) Average direct energy consumption

Figure 3. Average energy consumption by income classes

The direct energy is comprising basically for electricity, mobility and cooking. São Paulo has a proper supplying from Ethanol (56%) and refinery products (46%) while the Rest of Brazil has a excellent electricity supplying (80%). These sources impact directly the origin of the energy used by households. When we see the outside dependence (Fig. 3b), the structure is very similar with total energy dependence. In other words, most of the energy is supplying domestically. Sao Paulo have been used 85% inside energy and the Rest of Brazil about 87%.

4.2 Emissions

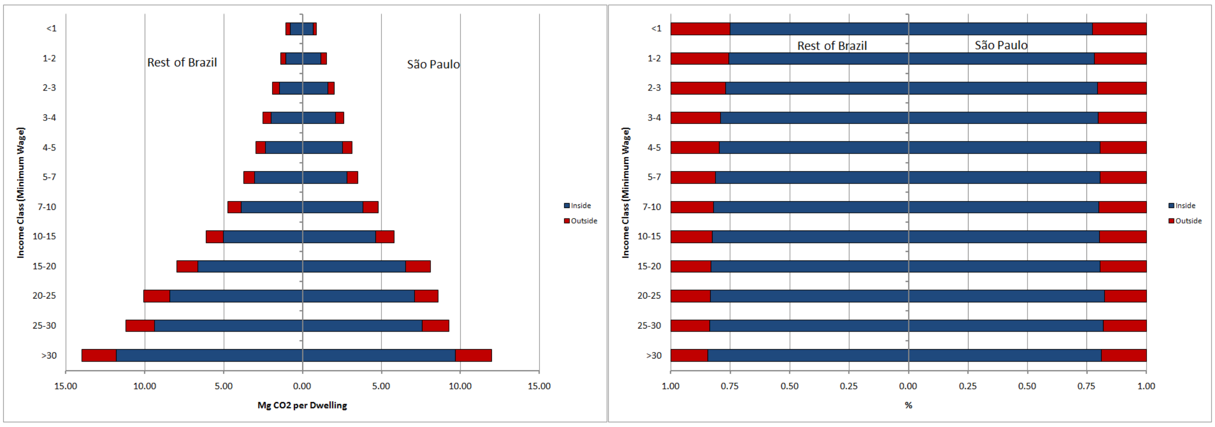
The emissions analysis between two regions are very similar (Fig. 4a). In both regions, the emissions per dwelling increase and the intensity falls when the level of income increases. The lifestyle highest income classes are related with a consumption of many industrial sectors that are associated with the use of more energy and consequently more emissions as showed by Feng et al. (2011). The highest class emit 13 time more than lowest class, but, in São Paulo, their is 3 time more than average while, in the Rest of Brazil, is 4.5 times greater. Opposite situation occurs when we compare the average with the lowest class, 4.5 to São Paulo and 3 to the Rest of Brazil (fig. 4b). when it comes to emissions, the lowest classes are less efficiently than highest classes. The lowest class is 4.8, to São Paulo, and 5.6, to the resto of Brazil, less efficient than the highest class. It's very hard to lowest class choose between cleaner goods and services and others, sometimes they don't have access to.



(a) Average GHG emissions (b) GHG emissions intensity

Figure 4. Average GHG emissions by income classes

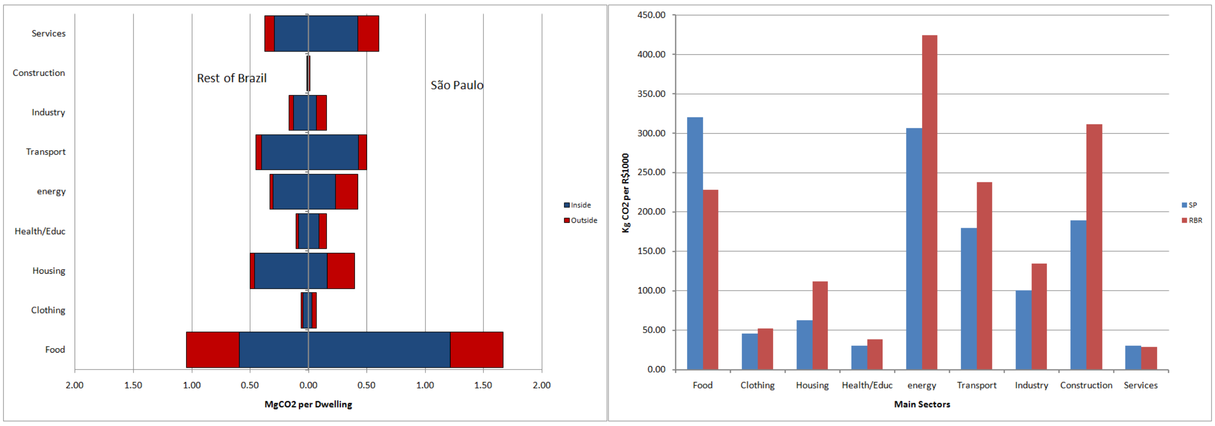
The proportion between emissions inside and outside are very similar (Fig. 5). In São Paulo, 20% are outside and the Rest of Brasil 19%. For the Rest of Brazil, the 5 lowest classes, the emissions are greater than, the same classes, São Paulo. About 23% and 21%, respectively. This can be explained for the weight of food in this classes and São Paulo be a greater importance in provider of processing foods.



(a) Average total GHG emissions (b) Share GHG emissions

Figure 5. Average GHG emissions by income classes

Sectorial, the top four source of emissions in São Paulo are Food, Services, Transporte and Energy. For the Rest of Brazil are Food, Housing, Transport and Services (Fig. 6a). This show that households in São Paulo are more polluters than the Rest of Brazil except in Housing and Industry. In São Paulo, the families has more access to goods and services and the income average are 40% more than the average to the rest of Brazil.



(a) Emissons per dwelling (b) Emissions per monetary unit

Figure 6. Average energy consumption by income classes

5 Conclusions

Sao Paulo state is less concentrated in income, energy and emissions than Rest of Brazil. The energy is concentrated than income in both regions, The access a source with low efficient in emission to lowest classes in Sao Paulo promote the desconcentration in emissions, this make the lowest classes more emission intensive than highest classes. This movement do not occur in the Rest of Brazil. This can be explain because of the diversity in terms of region, specially NE and N. the social program supply poorest people with electricity but not to offer others kind of energy and the poorest people have less access to good and services, in others words, less access to indirect energy

The energy elasticity is very similar between regions and positive such as many works showed. The increase in income will demand more energy. Emissions elasticity is very close to one, indicate that emissions will increase proportionality to growth of energy. this could be focus for policy makers in directions to a clean energy matrix. In this case, the pre-sal program has a special hole with the supply natural gas.

The energy consumption per dwelling shows the positive correlation between energy consumption and income. the direct energy has a saturation point. This make the direct energy consumption more important for the lowest classes. The highest classes consume more energy embodied. this because of ease of access to goods and services. The direct energy share in Sao Paulo is greater than Rest of Brazil.we expect the opposite The poorest region in Brazil has less access to commercial energy and this can explain the contradictory results.

We can observe that poorest classes are more energy intensive than highest classes and Sao Paulo are more efficient than the Rest of Brazil. Sao Paulo has access to energy more efficient. The food, services and transport are the most important sectors for all classes. The difference are in the shares. The food are more important for the lowest classes and the services for the highest.

The emissions between regions are very similar, in contrast with energy. The energy service come back to a region but the waste stay in local of processing. The food sector is the main emission sector per dwelling when the energy is the one per monetary unit.

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Appendix 4. Feasible triples for highly variable Grid, MLMMH.

Sectors	**Description**
Food	Agriculture and forestry Livestock and fishery Food and beverage Tobacco products
Clothing	Textiles Wearing apparel Leather and products thereof
Housing	Domestic appliances Passenger cars and commercial vehicles Furniture and other manufacturing products Electricity, gas, and water supply Services rendered to the families Private households with employed persons
Health/Education	Pharmaceuticals Medical, optical and measuring equipments Private education Private health care Public education Public health care
energy	Crude petroleum and Natural Gas Petroleum and petro products Ethanol
Transport	Lorries and buses Parts and accessories for motor vehicles Other transport equipment Transport and post activities
Industry	Mining of iron ores Other mining Wooden products, except furniture Pulp and paper Printing Basic Chemicals Plastics in primary forms and man-made fibres Pesticides Soap, cleaning and toilet preparations Paints, varnishes and similar coatings Other chemical products Rubber and plastics products Manufacture of non-ferrous metals Other fabricated metal products Industrial machinery Office, accounting and computing machinery

	Other electrical equipment Electronic components and communication equipments
Construction	Cement Other non-metallic mineral products Manufacture of basic iron and steel Construction
Services	Trade Telecommunications, computer and related activities Financial intermediation Real state and renting activities Maintenance and repair Hotels and restaurants Business activities Public administration and social security