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Carbon dioxide emissions of households in Mexico City

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Introduction

Climate change is a phenomenon studied from different perspectives, most of them from a quantitative point of view and at an aggregate level. The main population perspective of these studies has to do with energy consumption or generation of carbon dioxide emissions and other greenhouse gases, but without addressing social issues.

Energy consumption and associated carbon dioxide emissions are closely related to social conditions of people and practices that surround their daily reproduction. It is therefore necessary to approach them from a micro-social level. In Mexico there are no sources of disaggregated data on energy consumption or greenhouse gases emissions.

This is a void of useful information for designing policies and strategies which goals are to influence population energy consumption practices and thus to reduce greenhouse gases emissions. One way to solve this is studying energy consumption in households with income and expenditure surveys. These surveys contain data of household expenditure on electricity and fuel.

In a previous study, using data from the latest survey of income and expenditure, we find that not all cases of the sample reported spending on electricity and fuel. This is a problem of information quality that may be less important when we use data available for each Mexican state. One of the states with a representative sample is Mexico City -Distrito Federal.

Central idea of this proposal is to estimate carbon dioxide emissions of households in Mexico City. We propose to use spending on electricity and fuels reported in '*Encuesta Nacional de Ingresos y Gastos de los Hogares 2008'*.

It is useful to note that carbon dioxide emissions are generated from domestic activities such as feeding, lighting, personal care and housing, or entertainment, and associated electricity, liquefied petroleum gas, natural gas or firewood consumption.

In this approach, the analysis seeks to show the relationship between carbon dioxide emissions and household income and size. In order to measure emissions volume we will use emission average per household member.

As a result we expected that carbon dioxide emissions generated from household reproduction are higher: 1) In households in the highest income strata, and 2) In smaller households, according the principle of scale economies.

The objective is to verify if estimation method is appropriate as an approach to allow further study of the phenomenon.

If we achieve this goal, we will also show the relationship between carbon dioxide emissions and some of main demographic household characteristics. Among them, age and gender of household head.

1. *The origin of climate change.*

The empirical evidence collected in recent years and its contrast with previous records suggests that Earth's climate has changed. Key climate variables are used in this contrast. Some of them are the average temperatures in different regions of the globe, the thickness of the layer of snow at the poles of the earth, the extension of land ice and sea ice, or records of sea level in coastal and bays.

The instrumental record of global surface temperature, for example, suggests that eleven of the twelve years that comprise the period from 1995 to 2006 are among the warmest since 1850. Increases in sea level are consistent with this increase in temperature: between 1961 and 2003 global average sea level rose at an average rate of 1.8 mm per year. Similarly, available information indicates that the extent of Arctic sea ice has decreased by 2.7 percent per decade since 1978 (IPCC, *op. cit.*).

From these and other observations obtained, one can say with some certainty that many natural systems are being affected by regional climate changes, particularly by the increase in global temperature (IPCC, *op. cit.*). This temperature rise has generated interest for several decades, both to investigate their causes and to find ways to reduce their impact. Especially those related to human activity.

Climate change due to human activity is correlated with issuance of long-lived gases in the atmosphere. These are collectively known as greenhouse gases and include carbon dioxide, methane, nitrous oxide and halocarbons -a group of gases containing fluorine, chlorine or bromine. The concentration of greenhouse gases in the atmosphere increases when emissions exceed in magnitude the ability of natural absorption processes. Greenhouse gases are produced mainly by burning oil and its derivatives as a source of energy (IPCC, *op. cit.*).

The United Nations Framework Convention on Climate Change was held in May 1992. Its purpose was to lay the groundwork for a gradual stabilization of the concentration of greenhouse gases in the atmosphere. This is to prevent endangering the global climate system (UN, 1992).

Years later, in December 1997, the Kyoto Protocol to the Convention United Nations Framework on Climate Change was created. This document sets out government commitments to reduce and limit the volume of greenhouse gases emissions. One of the main lines of action proposed by this protocol is creation and expansion of environmental policies (UN, 1998).

Both documents were ratified by Mexican government. However, the Kyoto Protocol entered into force until February 2005 as a tool to guide environmental policy in participating countries. The main objective of the Kyoto Protocol is to reduce the emission of greenhouse gases and significantly reduce the use of fossil fuels like coal, oil and gas (UN 1998).

The guiding principles of Kyoto Protocol were taken up in Mexico with the *'Estrategia Nacional de Cambio Climático 2007*'. Its purpose is to reduce emissions of greenhouse gases into the atmosphere with more efficient patterns of energy generation and energy use, and less dependent on fossil fuels as an energy source (CICC, 2007).

Mexican strategy for climate change identifies the key determinants of emissions of greenhouse gases from energy generation and energy use in Mexico. These are population growth, economic activity and intensity of energy use. Also the mix of fossil fuels used in industrial, commercial, residential or public sectors, among others (CICC, *op. cit.*).

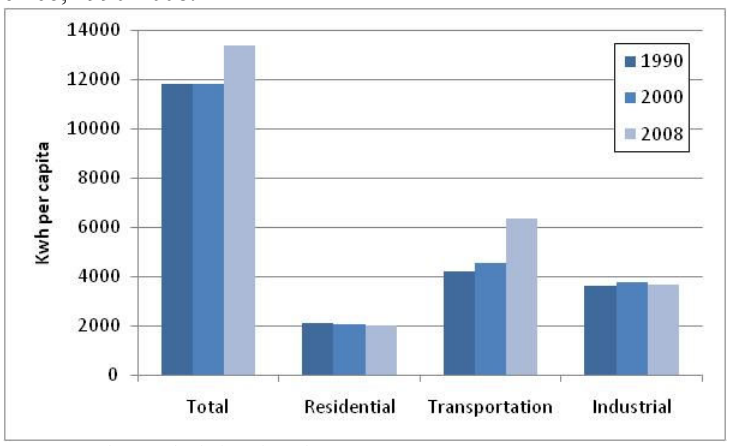
2. *Energy consumption in Mexico*.

In the last two decades, energy consumption in Mexico increased slightly over 43 percent. In 1990, 2000 and 2008, were consumed 3,570.6, 4,176.6, and 5,129.4 Petajoules in the country.

The figures for 2008 indicate that in transport sector were consumed 47.4 percent of 5,129.4 Petajoules, 27.3 percent in industrial sector and 15.0 percent in residential sector. The remaining 10.2 percent were consumed in commercial, public and agricultural sectors and in power generation (SENER, 2009).

This rate growth is greater than the observed in Mexican population. And suggest more intensive energy use. Energy consumption was 11,812 kilowatt-hours per capita in 1990, rose to 11,786 in 2000, and reached 13,356 in 2008. Trends are shown in Figure 1.

Figure 1. Per capita energy consumption by energy sector: Mexico, 1990-2008.

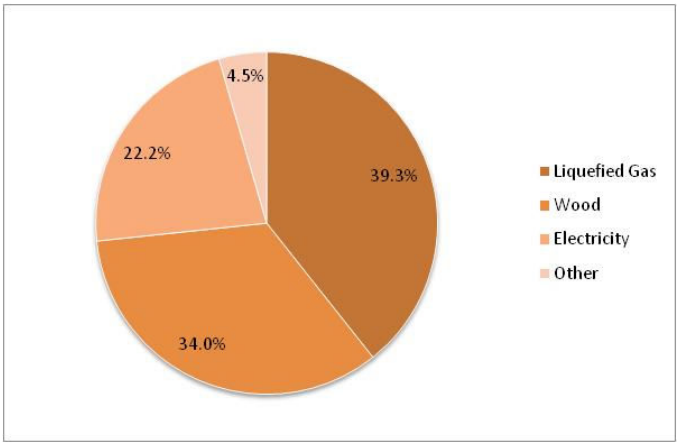


Source: Authors' calculations based on: SENER, CONAPO.

Figure 1 also shows that most notable energy consumption growth occurred in transport sector. However, residential sector presents some stability when measured as a function of population: 2,124 kWh per capita in 1990, 2,063 kWh per capita in 2000 and 2,007 kWh per capita in 2008.

In the other hand, main energy sources used in Mexican households are electricity, liquefied petroleum gas and firewood. 39.3 percent of the energy consumed for domestic use in 2008 came from the combustion of liquefied petroleum gas, 34.0 percent from firewood combustion and 22.2 percent from electricity use. The remaining 4.5 percent comes from the use of kerosene, natural gas and solar power among others. See Figure 2.

Figure 2. Energy use source in residential sector: Mexico, 2008.



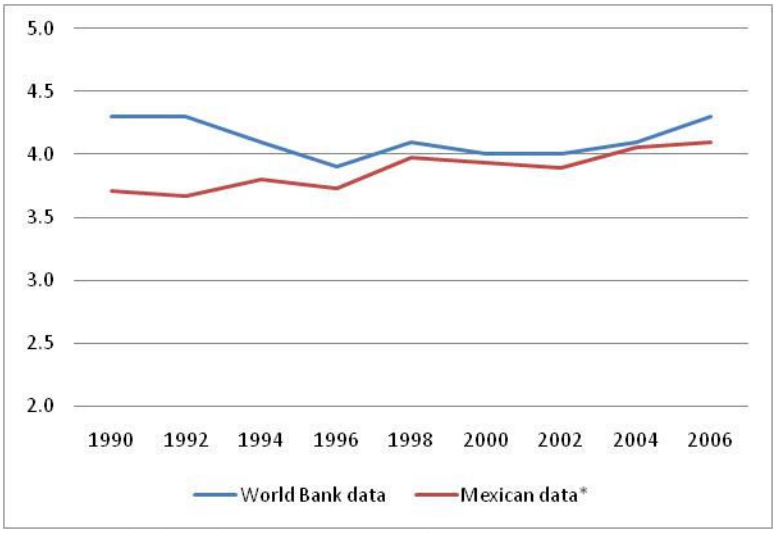
Source: SENER.

3. Carbon dioxide emissions in Mexico by the use of fossil fuels for energy.

Because anthropogenic emissions of carbon dioxide primarily are result from the combustion of fossil fuels, energy use is an important issue of the climate change debate. In Mexico, more recent estimates of greenhouse gases emissions were presented in the 'Inventario Nacional de Gases de Efecto Invernadero 1990-2006'. On this document data were organized in six emission categories: Energy, Land Use, Land Use Change, Forestry, Waste, Industrial Processes and Agriculture.

In Mexico, carbon dioxide emissions energy-related increased from 311,195 to 430,097 metric tons between 1990 and 2006. This is an increase of 38 percent in almost two decades (SEMARNAT/INE, 2008).

Figure 3. Carbon dioxide per capita emissions by energy use: Mexico, 1990-2006.



(*) Authors' calculations based on: SEMARNAT/INE, CONAPO.

Considering the population size, carbon dioxide emissions by energy use increased from 3.7 to 4.1 per capita metric tons between same years. According to Mexican data, this represents an increase of 10.8 percent. In Figure 3 we can see that this is a sustained increase throughout the period.

Figure 3 also shows the difference between Mexican data and World Bank data. This difference is most notable in nineties. In this regard we should note the tendency to homogenize estimation methodologies of carbon dioxide emissions.

Relative contributions of emission categories to total carbon dioxide emissions in Mexico have changed over time. In 2006, carbon dioxide emissions associated with energy use and consumption accounted for 60.7 percent of the country total. See Table 1.

Table 1. Carbon dioxide emissions by emission category: Mexico, 2006.

Emission Category	CO2 emissions (metric tons)	%
Total	709,005	100.0
Energy	430,097	60.7
Land Use, Land Use Change and Forestry	70,203	9.9
Waste	99,628	14.1
Industrial processes	63,526	9.0
Agriculture	45,552	6.4

Source: SEMARNAT/INE.

Carbon dioxide emissions associated with energy consumption represented 382,702 metric tons in 2006 -3.65 per capita metric tons. Carbon dioxide emissions from energy consumption in residential sector accounted 20,187 metric tons -0.19 per capita metric tons. That is, per capita carbon dioxide emissions generated by residential energy consumption reached 192 kilograms. See Table 2. [1]

Table 2. Carbon dioxide emissions from energy consumption: Mexico, 2006.

Energy sector	CO2 emissions (metric tons)	
	Total	Per capita*
Total	382,702	3.649
Power Generation	149,137	1.422
Transportation	144,691	1.380
Industrial	56,832	0.542
Commercial and agricultural	11,855	0.113
Residential	20,187	0.192

(*) Authors' calculations based on: SEMARNAT/INE, CONAPO.

[1] According to the methodological criteria of SEMARNAT/INE, the remaining 47,395 metric tons are generated by fugitive methane emissions.

4. *Carbon dioxide emissions of Mexican households.*

The energy consumption of households and associated carbon dioxide emissions depend on variables such as number of household members and time spent in their homes doing everyday activities. It is also linked to income and other characteristics of household members, such as age or sex. Also influence beliefs, values and expectations of welfare of household members, either collectively or individually. Contextual variables are the market prices of energy, incentives and subsidies to consumption, climate, regional economic dynamics or the availability of new technologies (Stern, *et al.*, 1997).

For that reason it is important to analyze as widely as possible carbon dioxide emissions from the perspective of the characteristics of households. It is about finding patterns, trends and regularities in carbon dioxide emissions, useful for the design of policy strategies.

Carbon dioxide emissions generated by residential energy use represent only a fraction of total emissions of this greenhouse gas. But they are generated by people's daily activities and can be viewed as energy consumption patterns more closely related to their practices, attitudes and values. Then, also affect the volume of carbon dioxide emissions.

Public policies could impact on these practices, attitudes and values, and it is very likely to change consumption patterns by reducing energy demand and the volume of carbon dioxide emissions associated. In the other hand, the results derived from this approach may be useful to guide research in a developing field, particularly in Mexico.

As noted in the introduction, the central idea of this proposal is to estimate carbon dioxide emissions of households in Mexico City. It is used information about spending on electricity and fuels in the database of ENIGH 2008.

This survey is representative of households throughout the country, and for households of some states. Distrito Federal data are used as a proxy of Mexico City households.

Carbon dioxide household emissions are generated from various domestic activities: food, lighting, household cleaners, personal hygiene, and entertainment. Results are presented only for the emissions generated by the consumption in households of electricity, liquefied petroleum gas, natural gas or firewood.

One issue to consider is that Mexico has various prices for domestic use of electricity. Prices also differ by region for liquefied petroleum gas and natural gas. For that reason we use weighted average prices.

Since there is not an average price of firewood, we use a price equivalent to 0.25 of liquefied petroleum gas prices, as proposed by Barnes *et al*. (2004). The prices used per unit of measurement, as well as conversion values are shown in Table 3.

We should note that survey data have a reference period of three months. Values are multiplied by four to estimate carbon dioxide emissions per year.

Table 3. Carbon dioxide emissions conversion factors: Mexico and Mexico City, 2008.

Energy	Measurement Unit	Megajoules	Emissions (KgCO2/Mj)	Unit price (pesos)	
				Mexico	Mexico City
Electricity	Kilowatt / hour	3.6	0.0162	1.06	1.06
LP Gas	Kilogram	45.0	0.0626	10.07	9.93
Natural Gas	Cubic meter	38.0	0.0566	7.21	7.10
Firewood *	Kilogram	16.0	0.0069	2.52	2.48

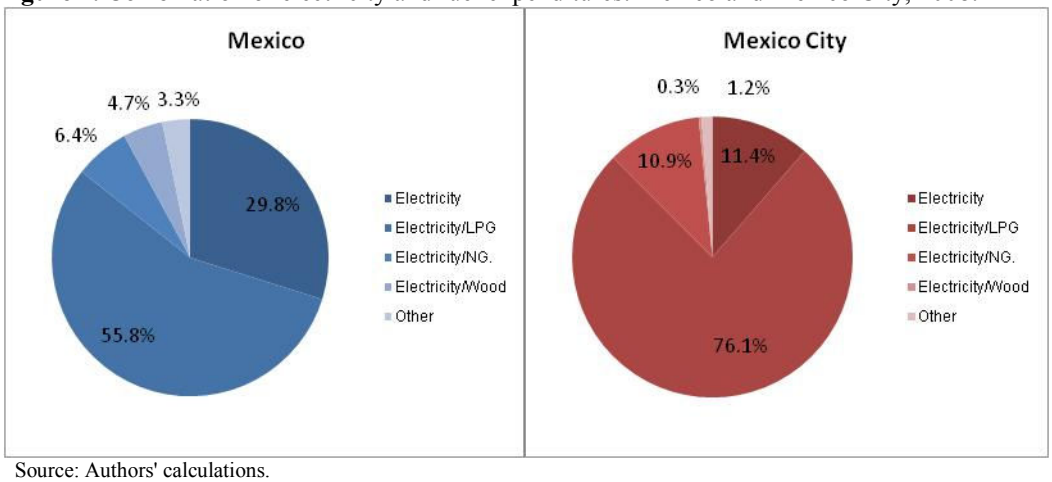
Source: Authors' calculations based on: Barnes, et al. (2004); DEFRA (2009); SENER.
(*) Consider carbon dioxide absorption.

One problem with survey data is that only 88 percent of households in national sample reported spending on electricity and fuel. In contrast, Mexico City (Distrito Federal) sample has 95 percent of households with information in this section of expenditure. Information comes from 25,931 and 2,415 households, respectively. This confirms that Mexico City data are more accurate.

On the other hand, according to survey data, there are different combinations of spending on electricity and fuels of households. In national sample, 29.8 percent declared spending on electricity, 55.8 percent on a mixture of electricity and liquefied gas, 6.4 percent on electricity and natural gas, 4.7 percent on electricity and firewood, and 3.3 percent on any of these fuels. See Figure 4.

In Mexico City sample, 11.4 percent of households reported spending on electricity, 76.1 on a combination of electricity and liquefied gas, 10.9 percent on a combination of electricity and natural gas, 0.3 percent on a combination of electricity and wood, and 1.2 percent on any of the fuels mentioned above.

Figure 4. Combination of electricity and fuel expenditures: Mexico and Mexico City, 2008.



Source: Authors' calculations.

So, household energy consumption has its own characteristics in Mexico City. For example, firewood is consumed in a lower proportion of households.

For national sample, under proposed estimation method, average carbon dioxide emissions per household member were 262.3 kilograms in 2008. This value is 36.6 percent higher than SEMARNAT/INE estimate in 2006 -192 kilograms. This suggests that our results might be overestimating the amount of emissions.

In Mexico City -Distrito Federal, the average carbon dioxide emissions per household member are 287.7 kilograms in the same year.

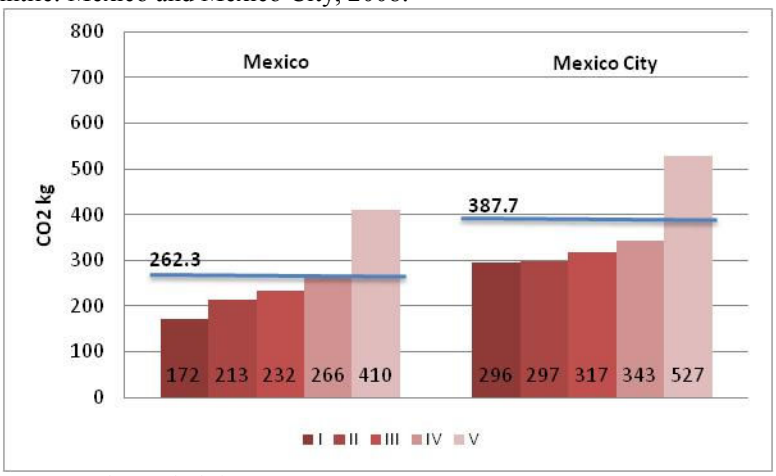
4.1 Carbon dioxide emissions of households in Mexico City by income and household size.

Our main results expected are: 1) Carbon dioxide emissions are higher in households in the highest income strata. 2) According to the principle of scale economies, carbon dioxide emissions are higher in households with smaller size.

In Figure 5 we can see that carbon dioxide emissions average per household member grows as the level of household income. This can be seen with Mexico data as well as Mexico City data.

This figure also shows that average carbon dioxide emissions per income quintile are higher in Mexico City than the national average. This leads to the conclusion that energy consumption is more intense in Mexico City. Even in lower income households.

Figure 5. Carbone dioxide emissions per household member by income quintile: Mexico and Mexico City, 2008.

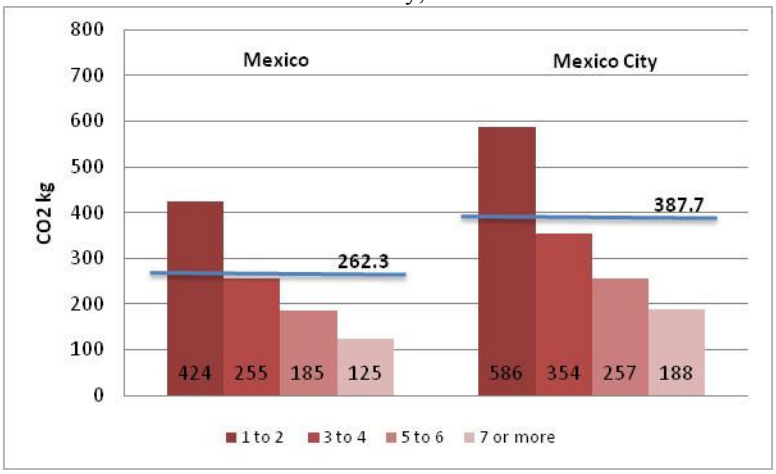


Source: Authors' calculations.

Figure 6 shows that average carbon dioxide emissions per household member decreases with household size. This is for the whole country and Mexico City. This is the expected behavior based on the principle of scale economies, but is not considered age composition of household[2].

[2]See: Mancero (2001).

Gráfica 6. Carbone dioxide emissions per household member by household size: Mexico and Mexico City, 2008.



Source: Authors' calculations.

The estimated carbon dioxide emissions per household member have similar behavior when using both national and Mexico City sample data. In this sense, we can say that it is possible to analyze with some degree of certainty the relation between carbon dioxide emissions and other household characteristics. Here are preliminary findings with some basic household characteristics:

4.2 Carbon dioxide emissions in households of Mexico City according to some household characteristics.

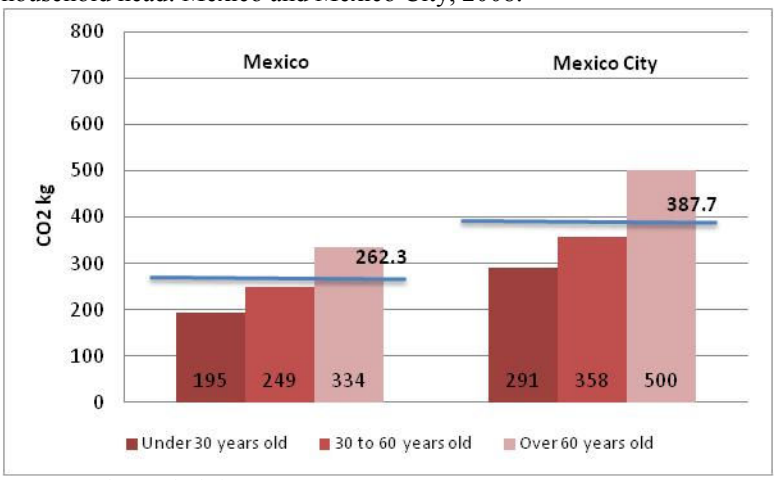
One of the main household characteristics is its age composition. We use the age of head of household to distinguish different groups of households.

Under this proposal, the average carbon dioxide emissions per household member grow with increasing age of household head. There are several possible causes for this behavior. One may be energy efficiency of appliances. Another may be use of new domestic technology. Both can be seen as research lines which can be exploited in the future. See figure 7.

gender of household members is another interesting characteristic. Below are associated carbon dioxide emissions with gender of household head. See Figure 8.

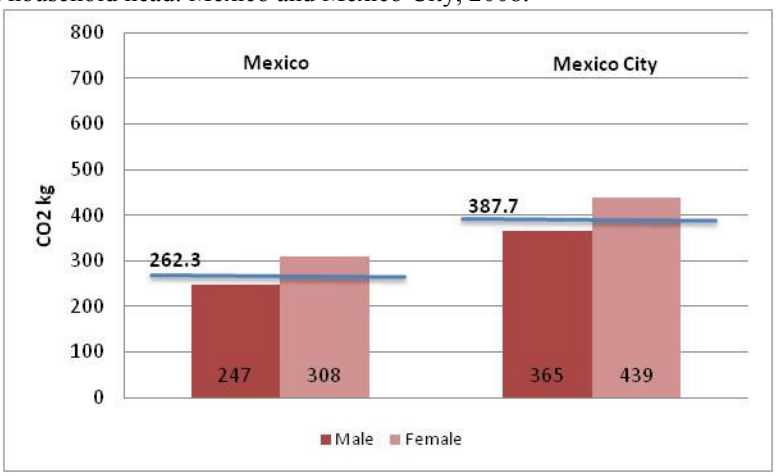
In this Figure one can see that average carbon dioxide emissions per household member are slightly higher in households headed by a woman than in a male-headed. This may be related to domestic work and with time use at home. It is also an interesting starting point for future research, to address the particularities of Mexican households.

Figure 7. Carbone dioxide emissions per household member by age of household head: Mexico and Mexico City, 2008.



Source: Authors' calculations.

Figure 8. Carbone dioxide emissions per household member by gender of household head: Mexico and Mexico City, 2008.



Source: Authors' calculations.

5. *By way of conclusion.*

It can be said that our estimated of carbon dioxide emissions behaves as expected. This occurs when carbon dioxide emissions are linked to household income, and in its association with household size.

Although the quality of information is different in scope, similar patterns were found using national sample and Mexico City sample. This suggests that use of household income and expenditure surveys can be useful for estimating carbon dioxide emissions, at least in regard to residential energy consumption.

It should address the study of carbon dioxide emissions determinants from a micro-social perspective. So, this estimation method can also be used to study other links between the characteristics of households and carbon dioxide emissions.

In fact, carbon dioxide emissions generated by domestic activity may also be analyzed using other household characteristics. For example, household members education level, number of rooms in the house, or available appliances such as television and refrigerator. In the case of households owning motor vehicles, we might study information about spending on diesel or gasoline.

Since there are no sources of specialized information on household energy consumption, this approach is a good way to find answers that address the diversity of family arrangements in Mexico. The study of such diversity could contribute to better construction of policy strategies.

As final consideration, because we might have overestimated carbon dioxide emissions amount, it should be noted the need to evaluating the source information quality.

Reference

Barnes, Douglas, et al. (2004). *The Urban Household Energy Transition. Energy, Poverty, and the Environment in the Developing World*. World Bank, March 2004.

CICC (2007), *Estrategia Nacional de Cambio Climático. México 2007*. Comisión Intersecretarial de Cambio Climático. Mexico.

CONAPO (2006). *Proyecciones de la población de México 1990-2030*. Mexico.

Cortes, Fernando. (2003). "Acerca de la medición oficial de la pobreza en México en el año 2000". Estudios Sociológicos, Vol. XXI, 2. El Colegio de México: pp. 463-470.

Damián, Araceli (2007), "Los problemas de comparabilidad de las ENIGH y su efecto en la medición de la pobreza". Papeles de Población, 51, UAEM. Mexico: pp. 111-146.

DEFRA (2009). *Guidelines to DEFRA/DECC's GHG Conversion Factors for Company Reporting*. Department of Energy and Climate Change. United Kingdom

IILSR (2003). *Información Básica de las Tarifas Eléctricas en México*. Instituto de Investigaciones Legislativas del Senado de la Republica, Mexico.

INE (2007). *Estrategias para enfrentar el cambio climático. El caso de México*. Seminario sobre cambio climático: el caso de México. Academia de Ingeniería, Mexico.

INEGI (2009). *Encuesta Nacional de Ingresos y Gastos de los Hogares 2008*. Cambios y Adiciones. Mexico.

IPCC (2007): *Cambio climático 2007: Informe de síntesis*. IPCC. Geneva Switzerland.

Mancero, Xavier (2001): *Escalas de equivalencia: Reseña de conceptos y métodos*. Serie Estudios estadísticos y prospectivos 8, CEPAL. Santiago de Chile, March 2001.

ONU (1992). *Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Naciones Unidas, Nueva York, USA.

ONU (1998). *Protocolo de Kioto de la Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Naciones Unidas. Kioto, Japan.

SENER (2008). *Balance Nacional de Energía 2008.* Secretaría de Energía, Mexico.

SEMARNAT (2009). *México. Cuarta Comunicación Nacional ante la Convención Marco de las Naciones Unidas sobre el Cambio Climático*. Secretaría de Medio Ambiente y Recursos Naturales/Instituto Nacional de Ecología, Mexico.