Determinants of GHG emissions from urban ground transportation: review on a sample of European cities

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Introduction

The role of cities in climate mitigation policies has grown in recent years and has consequently received more attention in economic literature. Households and companies located in cities consume relevant amount of energy for their everyday activities and needs, which give rise to GHG emissions. Furthermore, they consume and import several services and goods, whose production gives rise to emissions also outside the urban area.

GHG inventories of cities usually report emissions produced within a defined boundary applying a "territory principle": GHGs are assigned to the location where gases are emitted (e.g. location of fuel combustion or consumption). In specific cases, an "activity principle" is applied and GHGs are assigned to the location where the activity generating emissions takes place, even if gases are emitted outside the defined activity boundary (e.g. emissions from imported electricity are allocated to the city). A relevant issue in the inventorying process is thus to identify the spatial area and the activities that should be included or not in the estimation (Bader and Bleischwitz, 2009).

Most of published urban inventories focus mainly on emissions from energy uses in several activity sectors. Emissions embedded in products and services consumed within a city – i.e. emissions generated along their complete life cycle: production, use and disposal - are more rarely included in urban inventories, because of the complexity of methods and scarcity of data. UN-Habitat (2011) highlights that, since no unique definition of city and no globally accepted standards to allocate emissions to cities are available, figures about the contribution of cities to global emissions should be considered with caution. Reporting the results of an estimation based on the location of emissions production, they suggest that cities are probably responsible for 30-40% of anthropogenic GHG emissions. According to other sources, the contribution of all urban areas to global emissions, including also towns and other urban settlements, is in the range 40-70% (Walraven, 2009, in UN-Habitat, 2011).

Inventories show that levels of urban emissions per capita can differ considerably in the world, from 2 to 30 tCO_2eq (Dodman, 2009; Kennedy et al., 2009; Sovacool and Brown, 2009). Differences in emissions levels depend on specific local features: climate conditions, urban form, demographic features, economic activities in place, state of technology, mobility and housing infrastructures and prices, income and life style of city residents and users (UN-Habitat, 2011; Croci et a., 2011).

Climate determines the energy needs to heat and cool buildings throughout the year. Urban morphology is related to the city's shape and compactness, which have an influence on energy efficiency in buildings and transportation. Urban economy contributes to shape the overall GHG emissions of a city, according to the typologies of activities in place (e.g. service oriented city vs. manufacturing city). The availability of specific infrastructures, such as district heating network, metro lines and other mass transportation systems provides a low carbon alternative for heating and mobility. The prices of different fuels and transportation modes have an influence on local emissions, according to the price elasticity of demand of consumers. Income has an influence on the quantity and typology of consumption, also in terms of its carbon content. According to their lifestyle, personal habits and also age, citizens and city-users have different travel habits, which impact energy use and emissions.

The paper focuses on GHG emissions of European cities from transportation. Urban mobility is currently a relevant issue in European policies on climate change and urban environment. This is due not only to the impact of this sector on GHG emissions, but also to its implications on quality of life. At European level, urban transport is responsible for about 23% of total CO_2 emissions from transport, of which 70% are due to passenger cars and 27% to goods transport vehicles (EC, 2011). But the sector is also responsible for most of air pollution emissions, and for high levels of congestion and noise which impact health and wellbeing of citizens and city-users. Reducing GHG emissions therefore generates also other environmental and non-environmental co-benefits: for this reason, the theme becomes important in the agenda of urban policies.

Passenger transport, in particular, offers interesting options to abate emissions: estimates suggest that emissions could be abated up to 88% in comparison to an unchanged policy scenario, if the following measures were applied: fuel efficiency standards (44% of reduction), decarbonisation of energy supply (42%), spatial planning and shift to non motorized modes and public transit (2%) (EC, 2011).

The purpose of this analysis is to explore the determinants of GHG emissions from urban transport. We make use of available data at European level to evaluate through a linear regression a set of variables and to determine their relevance in influencing emissions. A sample of 29 to 33 European cities is considered[1]. Urban emissions reported under the "Covenant of Mayors", a voluntary commitment signed with the European Commission, are put in relationship with socio-demographic, economic, infrastructural and geographical data from the Urban Audit, a European database on cities (Eurostat, 2010).

The paper is structured as follows:

1) In the first part, emissions from urban transport are decomposed in key factors and some underlying determinants of these factors are commented.

2) In the second part, a model for emissions from urban transport is presented

3) In the third part, data sources are presented

4) The final part is dedicated to the discussion of results.

[1] The different number of observations considered in the three models is due to data limitations.

1. Decomposition of emissions from urban transport

GHG emissions from ground transport at city level depend on the amount of transport demand of residents and city users and the modes through which this demand is satisfied. Grazi and van den Bergh (2008) highlight four "mechanisms of change" concerning GHG policies in the transport sector, which could be activated through specific measures: (1) transport volume carried out within the city, expressed in trips or kilometers travelled; (2) the modal split, that is the composition of traffic between freight and passenger transportation and the extent to which different modes are employed to move goods or are chosen by people to travel (3) energy efficiency of motorized modes according to the technological features of the operating vehicle fleet and (4) fuel types used, each characterized by different carbon contents.

Several identities can be used to describe emissions from ground transport. Each identity highlights factors that contribute directly or indirectly to energy use and GHG emissions from transport (Darido et al., 2009).

Identities (1) and (2) have been chosen for discussion in this paper. They represent emissions as a product of factors and show key differences between passenger and freight transport.

$$Et_{passengers} = \sum_{i=1}^{f} \sum_{j=1}^{m} (T_j \times L_j \times lf)_i \times EF_{ji}$$
(1)

$$Et_{freight} = \sum_{i=1}^{f} \sum_{z=1}^{n} VKT_{zi} \times EF_{zi}$$

(2)

Where:

Tj = number of passengers' trips with "j" mode

Lj = average length of a single trip with "j" mode (passengers km)

lf = load factor of "j" mode (n. passengers/vehicle)

EFji = emission factors of "i" fuel with "j" mode (gCO_2/vehicle km)

f = 1, … 6

1 = gasoline

2 = diesel

3 = LPG

4 = electricity

5= other

6 = no fuel

m = 1, … 6

1 = foot

2 = bicycle

3 = subway/rail

4 = bus (and related sub-categories)

5 = passenger car (and sub-categories)

6 = motorcycle (and sub-categories)

VKTzi = kilometres travelled by freight vehicles of “i” fuel and of “z” mode (vehicle km/inhabitants)

EFzi = emission factors of “i” fuel with “z” mode (gCO_2/vehicle km)

z = 1,…3

1 = light duty vehicles (and sub-categories)

2 = heavy duty vehicles (and sub-categories)

3 = rail

Both equations have the same structure: they are composed by the product of transport activity (kilometres travelled) and the specific CO2 emission factor of vehicles/mode used to perform the travel.

For passenger transport, demand is represented by two factors, which taken together represent the overall transport volume generating emissions: the number of trips and the average trip length. Each mode is characterized by a specific average trip length, which can vary according to the typology of user (e.g. commuters commonly perform longer trips than city residents) and to the kind of mode (e.g. trips made with non-motorized modes are usually shorter than motorized trips). Furthermore, specific urban features can contribute to incentivize shorter or longer trips, such as the extent of the city area and its spatial organisation. For motorized modes, in addition to factors representing transport demand, technological features are highlighted in the equation through emission factors, which are different according to vehicle categories and to fuels consumed.

For freight, transport volume is represented by vehicle kilometres travelled, resulting from the number of freight vehicle trips for the length of trips. As for passenger transport, several conditions can influence the patterns of goods within the city and determine the average trip length of goods vehicles (e.g. city dimension, urban form, localization of commercial activities and warehouses). As well as private motorized vehicles, freight vehicles are characterized by a specific emission factor according to vehicle category and fuel used.

Several factors influence both transport activity and the average emission factor of each transport mode. They are briefly summarized in the following section.

Demographic and socio-economic features of population

Socio-demographic trends in Europe show that population is ageing, that women have longer life expectancy and that the average size of families is declining (Gerőházi et al., 2011). These trends have an impact on GHG emissions from transport that must be explored, since age, gender and family structures influence personal mobility patterns and the choice of travel modes.

The quantity, typology and length of trips we perform change with age. It could be supposed that young people and adults make more trips than elderly people, because they perform everyday journeys to the study or workplace, whereas old-aged people stay more frequently at home. Furthermore, the number of impairments that can affect mobility grows with age (Tacken, 1998).

Also the choice of transport mode is influenced by several variables (i.a. accessibility, comfort, safety, price) whose importance can differ according to age and gender. For example, low accessibility and low comfort can be obstacles for older people using public transportation. Perceived unsafeness can induce women not to use transit after dark. These conditions can favour car use, which is often seen as a mode that can ensure higher safety and flexibility of use (Li et al., 2012).

Considering income, increases in average income are usually connected with a rise in car ownership, but ownership rates are not necessarily associated with car use (Gerőházi et al., 2011). This suggests that other conditions, specific to the city (urban density, infrastructure, population, user cost of transport modes) can have a strong impact on travel decisions and need to be investigated.

Several works have explored the relation between socio-economic characteristics and mobility patterns. A recent paper by Barla et al. (2011) focuses on greenhouse gas emissions from urban travel in the Quebec City area and takes into consideration, among other variables, the impact of individual and households characteristics on different emission levels. The study finds that GHG emissions from urban travel differ depending on the gender of the responder (female produce 25% less emissions than males), age (emissions peak in the range 35-49 years old and decline after 65 years old), family structure, professional status and income level (average emissions per respondent seem to increase with income, household size and employment).

Urban form

The relation between urban form and travel has been analysed extensively. Several authors have compared travel data of cities worldwide and found a correlation between city density and reduced energy consumption for travel. However, when socio-demographic variables are included in the analysis, land-use looses part of its significance (Van de Coevering and Schwanen, 2006).

Newman and Kenworthy (1989) were among the first to address the density-travel nexus. Their study compared travel data from 32 cities of Europe, North-America, Australia and Asia, and found that population density is strongly and negatively correlated with energy used for transport. As highlighted by Van de Coevering and Schwanen (2006), their work has been criticized because of the lack of multivariate analysis and of control for variables that have an influence on the amount of travel (fuel prices, economic situation, demographic structure). The sample was later expanded to 46 cities (Kenworthy and Laube, 1999), and to 84 cities (Kenworthy, 2003), confirming the relevance of urban density on containing energy use. A following analysis by Van de Coevering and Schwanen (2006) on data used by Kenworthy and Laube showed that urban form is indeed relevant for metropolitan travel-patterns, but also socio-demographic, housing and history-related variables are statistically significant.

Several authors have highlighted that it is not density per se that reduces transport activity in terms of transport and length of trips, but it is rather the spatial distribution of places (jobs, dwellings, services) within the city. Bertaud (2004) shows how density distribution can affect the average length of trips in cities with the same average density. He also shows how dense cities are incompatible with the use of private cars, since limited availability of space generates a competition between land uses. He remarks that public transport needs high densities to be financially feasible, because a certain amount of potential customers must be located within the catchment area of each station or stop in order to justify the investment in infrastructure.

Commuting

The presence of workplaces and services in cities, both large and medium-sized, attracts people from the surrounding urban area, determining the flow of in-commuters and consequently a rise in transport activity within the city area. In European cities, commuting patterns are complex and they are often not limited to trips from periphery to the centre; the localization of jobs and commercial activities in the urban fringe also generates a out-commuting flow, which contributes to traffic and congestion (ECOTEC, 2007).

Commuter modality differs significantly between European cities, and this has important implications for emissions. Cities in United Kingdom show relevant share of car use in commuting (80%), and in other countries such as Italy and Belgium the share of cars arrives to 60%. On the contrary, in the new Member States public transport is highly used for commuting. Historical reasons are behind this peculiarity, such as the rigid planning distinction between urban and rural areas realized in these countries and the greater importance given to transit infrastructure discouraging private consumption in planned economies; this trend is now being reversed by increasing suburbanization and affluence, which drives a wider uptake of car use (ECOTEC, 2007).

Public transport infrastructure

The availability of a good network of public transport should incentivize citizens and city-users to prefer transit to their private cars. This incentive effect does not only depend on “quantitative” features of the network (length of the network, number of lines) but also on the quality of the network and its perceived quality by customers. Poudenx (2008) attributes the failure of certain policies limiting car use to the insufficient level of quality of transit services which are proposed as alternative to the private mode.

UITP (2010) underlines that public transport customers have relevant expectations from transit services in terms of quickness, safety, affordability, reliability, cleanness and availability of accessible and comprehensible information on travel options. Policies that enhance service quality targeting some of these aspects, for example improving connections and reliability of time schedules, providing innovative services such as bike-and-ride or park-and-ride, investing in weather protection for stops and improvement of stations, have proven to be successful in increasing the share of transit[2].

Relative price of transport modes

Prices affect travel demand in a significant and complex way. Changes in prices can regard and impact each component of travel: the number of trips, their destination and path, mode, travel time, type of vehicle, parking location and duration (Institute for Transport Studies, 2004). Furthermore, price sensitivity is influenced by several factors, such as (1) the type of price change, that determines which travel component is affected by the variation in price (e.g. fees on the vehicle; fuel price; fixed toll; congestion charging; parking fees; transit fare); (2) the type of trip and of traveler (commuting vs. occasional trips; weekday vs. weekend trips; urban high-peak period vs. low-peak period trips); (3) the quality and relative price of travel alternatives (routes, modes, destinations); (4) the time period (short vs. long term); and finally (5) how specifically or generically transportation is defined (VTPI, 2011).

With his milestone work, McFadden (1974) showed the relevant relations between prices and urban travel. According to his analysis, car travel demand increases when car costs for users fall, income rises and prices and waiting time for public transportation rise. Viceversa, he showed how car travel demand decreases with an increase in car costs for users and how they generate a higher demand for public transportation.

2. Methodology

Several variables, namely socio-demographic, economic, physical and spatial variables, have a significant influence on mobility patterns and emissions. In this paper they are jointly analyzed, making use of homogenous urban data. However, due to the small size of available dataset (29-33 cities)[3] only a subset of variables is considered for the analysis.

The model of emissions from urban transport considered in the paper takes the following form:

E = f (Density, GDP, Age-Mobility, Education, PTRelativePrice, Incommuters)

Where

[2] e.g., Poudenx (2008) reports the successful example of five European urban regions (Hamburg, Munich, and the Rhein-Ruhr region in Germany, Vienna in Austria and Zurich in Switzerland), that have focused their transportation policies on transit development and improvement. Two of them have managed to increase the number of transit trips on the overall number of motorized ones, and the other three have managed to contain the drop of transit modal share in a context of rising number of trips, due to increases in population and mobility.

[3] The different number of observations in the models is due to data limitations.

“E” are CO2 emissions from ground transport per inhabitant (tCO2)

“Density” is the number of residents per unit of land area (inhab/km2)

“GDP” is the Gross Domestic Product of the NUTS3 region per inhabitant in PPS (€)

“Age-Mobility” is the percentage of residents with low mobility on the total population (residents aged > 65 years + residents aged < 14 years / total resident population)(%)

“Education” is the proportion of population aged 15-64 qualified at tertiary level (ISCED 5-6) %

“PTRelativePrice” is the relative price of public transportation to private transportation (Cost of a monthly ticket for public transport (for 5-10 km) / price of 1 litre of gasoline + cost of 1 hour parking in the city centre + fee of 1 entrance in the congestion pricing zone, if present)

“Incommuters” is the amount of commuters the city attracts for its workplaces (proportion of incommuters of persons employed in the city)(%)

The following regressions have been applied:

Model 1.

$E_1 = \alpha_1 + \beta_1$ Density + γ_1 GDP + η_1 Age-mobility + δ_1 Incommuters + ε_1

Model 2.

$E_2 = \alpha_2 + \beta_2$ Density + γ_2 GDP + η_2 Age-mobility + δ_2 PTRelativePrice + ε_2

Model 3.

$E_3 = \alpha_3 + \beta_3$ Density + γ_3 GDP + η_3 Age-mobility + δ_3 Education + ε_3

All of the models are estimated using OLS.

There are some studies that suggest GDP might be related to CO_2 emissions in a non-linear way (see Galeotti et al., 2006, for an extensive literature review on the topic). Therefore, we perform a test of non-linear relationship, including GDP^2 into the model and then testing joint significance of GDP and GDP^2. The test results show no support for non-linearity hypothesis. For this reason it was decided not to include GDP^2 into the models. .

Furthermore, a correlation test was performed to estimate how much GDP and education are correlated between themselves in order to eliminate possible bias. The results show a moderate correlation (0.3915), so it was decided to include both variables in the third regression.

It should be noted that no variables related to technological features of the vehicle stock were included in the models. This was due to data limitations on the composition of in-use vehicles in the cities analyzed and also to the necessity to limit the set of explanatory variables. We suggest that these aspects shall be considered in future developments of the study.

3. Data

Emissions data were extracted from documents submitted by Local Governments for their compliance with the Covenant of Mayors[4] initiative. Since standardized urban emissions data are not available yet at the international level, it was decided to refer to a wide-scale emissions reporting scheme which could give a sufficient amount of data to support a quantitative approach. At European level, the CoM is giving a significant impulse in the direction of urban CO_2 reporting and emissions reduction planning. Covenant signatories cities are expected to develop and implement Sustainable Energy Action Plans (SEAPs) grounded on Baseline Emissions Inventories (BEIs), which they commit to regularly update and monitor.

Data regarding explanatory variables were extracted mainly from the Urban Audit[5] database, apart for some data related to the relative price of public transportation[6].

[4] Launched in 2008 by the European Commission, the Covenant recognizes the role of local governments in the global challenge against climate change and commits city mayors to go beyond the so called “20-20-20” targets related to the reduction of CO_2 emissions, energy efficiency and energy saving, and the increase of energy use from renewable sources. At this purpose, cities are expected to develop set of actions in several relevant fields (Sustainable Energy Action Plans, SEAPs). The participation in the initiative has grown exponentially in 3 years; nowadays, more than 3.000 local authorities from the 27-Member States, and some non EU-countries as well, are part of the Covenant. Of these, more than 800 have submitted a SEAP. The CoM initiative provides non-binding recommendations on the compilation of SEAPs and BEIs in order to ensure flexibility to participating cities, allowing for different approaches and methodologies to be used for the estimation of city emissions and the elaboration of emission reduction measures. According to the CoM guidelines, emissions from private passenger and freight transport are reported together. For this reason it was not possible to disaggregate emissions data into the two categories.

[5] The Urban Audit is a comprehensive data collection process taking place since the 2000s, after a pilot phase conducted in the late 90’s, targeted at providing comparative information on selected urban areas in Member States of the European Union and the Candidate Countries. Several aspects related to quality of life are considered in the process, in brief: demography, social aspects, economic aspects, civic involvement, training and education, environment, travel and transport, information society, culture and recreation. Data collection takes places every three years and an annual collection is foreseen for a limited set of variables The first collection (2003/4) has been carried on 258 participating cities; the second (2006/7) regarded 321 cities from the 27 Member States and 36 additional cities in Norway, Switzerland and Turkey; the third collection (2009) will be completed in 2011 (http://epp.eurostat.ec.europa.eu/portal/page/portal/region_cities/city_urban; http://www.urbanaudit.org/).

Within the Urban Audit, data are collected at four spatial levels: the Core City, according to the administrative definition; the Larger Urban Zone, which is an approximation of the functional urban zone which has its centre in the city; the Kernel, a special zone created for specific capital cities for which the use of the Core City level does not provide a unit comparable with other cities in the database; the Sub-City district, a subdivision of the city based on population criteria (for reference: Eurostat (2010). In the paper, data referred to the Core City level has been used, to ensure consistency with emissions data which refer to the administrative boundaries of the Local Authority.

[6] For a few cities, data on the average cost of a monthly ticket were unavailable in the Urban Audit database, so they have been integrated with data of the transit operators; data on congestion charge fees are published by the congestion scheme operator; fuel prices are from the Market Observatory for Energy of the European Commission (http://ec.europa.eu/energy/observatory/oil/bulletin_en.htm).

Table 1. Emissions per capita (tCO_2 or tCO_2eq) of the sample cities

City name	Unit	tCO_2/p.c.	Year	City name	Unit	tCO_2/p.c.	Year
Bruxelles	CO2eq	0,80	2007	Bologna	tCO2	1,34	2005
Aarhus	CO2eq	1,65	2007	Padova	tCO2eq	1,60	2004
København	tCO2eq	0,87	2005	Rīga	tCO2	1,00	2005
Hamburg	tCO2	2,52	2007	Amsterdam	tCO2	0,68	2006
Frankfurt am Main	tCO2eq	2,44	2005	Tilburg	tCO2	0,94	2004
Stuttgart	tCO2	1,76	2005	Lisboa	tCO2	2,96	2002
Bremen	tCO2	2,84	2005	Porto	tCO2	1,99	2004
Hannover	tCO2eq	1,72	2005	Stockholm	tCO2	1,11	2005
Nürnberg	tCO2	2,06	2004	Jönköping	tCO2	2,73	1990
Freiburg im Breisgau	tCO2eq	1,79	2005	Örebro	tCO2	0,64	2008
Karlsruhe	tCO2	2,18	2007	London	tCO2	1,34	2006
Barcelona	tCO2eq	0,65	2008	Birmingham	tCO2	1,54	2005
Málaga	tCO2eq	0,93	2008	Glasgow	tCO2	1,37	2006/07
Vitoria/Gasteiz	tCO2eq	0,74	2006	Manchester	tCO2	1,61	2005
Dublin	tCO2	2,33	2006	Bristol	tCO2	1,13	2005
Milano	tCO2	1,09	2005	Bergen	tCO2eq	1,69	2007
Torino	tCO2	0,82	2005	Kristiansand	tCO2eq	2,07	2006
Genova	tCO2	0,81	2005				

Reference year for emissions values differs among cities because each city government has elaborated autonomously its emissions inventory. The recommended baseline year within the Covenant of Mayors is 1990. If 1990 data are not available, the Local Authority can make use of data referred to subsequent years, provided that data are sufficient and reliable (JRC, 2010).

4. Results

Table 2. shows OLS results. Column 1 contains estimation results of Model 1. Here all variables are significant, except for GDP. All the variables are positively related to emissions, except for population density.

In the second column, there are estimation results of Model 2. Here, only population density and PT relative price are significant. GDP and Age-mobility are not significant. Again, population density is negatively related to emissions, while all of the rest variables show positive relationship with the dependent variable.

In the third column with estimation results of Model 3, coefficient on population density is again negative and significant. Coefficient on GDP, however, is now significant and positive. Education and age-mobility are not significant.

Table 2. Results of the three models

Emissions	1	2	3
Density	-0.0103851*** (-2.60)	-0.0083541** (-2.23)	-0.0072261* (-1.95)
GDP	0.0111885 (1.17)	0.0055016 (0.54)	0.0195777** (1.97)
AgeMobility	9.389698** (2.40)	4.328727 (1.04)	5.280651 (1.21)
Incommuters	0.0143766** (2.24)		
PTrelativeprice		1.256129* (1.90)	
Education			-0.0290701 (-1.59)
constant	-2.102722 (-1.51)	-0.2709379 (-0.18)	0.1247897 (0.07)
# Observations	32	29	33

Note: ***- 1% significance level; ** - 5% significance level; * - 10% significance level
t-statistics in parenthesis
Different number of observations in Models 1, 2 and 3 is due to data limitations.

Looking at the results per variable, the significance of population density and its negative correlation with emissions stands out as the most robust result. The variable results significant in all the regressions performed. The analysis confirms that cities with a compact built environment generate lower levels of emission from transport activity.

Coefficient on GDP is always positive, but it is significant only in the third regression. This positive relationship could be due to higher levels of private motorized transport activity or due to a more powerful, and more emissive, vehicle stock.

AgeMobility is significant only in the first regression and shows a positive relationship with emissions. This result is in contrast with our first hypothesis that a high percentage of non-active people (elderly and young) on total residents would be associated with low emissions from transport. However, as a robustness check, we estimated the same models but including the value of old age dependency index (people with more than 65 years / active population) instead of AgeMobility. The results confirms our finding of positive relationship between emissions and population's age. This outcome could be explained by a more frequent use of private motorized modes by old-aged people, that results in higher emissions. These modes are probably perceived as more comfortable, safer and more readily accessible than public transportation.

Incommuters is included only in the first Model and is quite significant. This confirms that commuting contributes to urban emissions with an uprising effect. Further research is needed to explore the modal share of commuters and how much this can influence transport emissions.

PT relative price is included only in the second Model and is significant at 10% level. The positive sign can be explained by the modal shift towards motorized modes induced by an increase of the relative price of transit.

Education is included only in the third Model and is not significant. However, the negative sign could suggest that a higher level of education could be associated with more awareness for environmental issues in transport and consequently with more eco-friendly mobility choices.

Conclusions

Several studies have explored the determinants of urban emissions from mobility and of their main components: travel demand and modes employed to satisfy such demand. Our paper makes use of data available at European level to analyse jointly the relevance of several determinants related to socio-demographic, economic and physical features of cities in influencing emissions values. The small size of the sample limited the study to consider only a subset of variables, which were tested in three different models.

The main results of the analysis confirm the relevant and negative correlation of population density with transportation emissions, even considered jointly with other explanatory variables, as ensued from previous studies published in literature.

For the other variables included in all the Models (GDP, AgeMobility), results are not as strong, since they are significant only in one case. Variables that were included only in one Model are significant (Incommuters, PTrelativeprice) or almost significant (education).

Values obtained for the coefficients in the regressions suggest us that it is necessary to expand the sample of cities and that these dimensions deserve to be further examined. In particular the variable “education” could be replaced by other proxy variables of environmental awareness of the population.

Furthermore, it is necessary to complete the analysis of emission determinants including variables related to technological aspects of the private vehicle stock, which is a major source of emissions at urban level. This type of investigation could be hampered by data limitations regarding the composition of the in-use vehicle stock in cities.

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