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Analysis

Urban Spatial Form and Structure and Greenhouse-gas Emissions From Commuting in the Metropolitan Zone of Mexico Valley

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ABSTRACT

A considerable proportion of the greenhouse gases (GHG) emitted into the atmosphere is attributable to transport. In the case of large cities, GHG emissions associated with transport—especially commuting mobility—can be reduced by acting on the built environment. According to the Compact City Approach to urban sustainability, the amount of energy per capita used to move within a city—and therefore GHG emissions—can be reduced by increasing the density and mix of residential and economic functions and directing the city's growth toward greater centralization, or concentrated (not dispersed) decentralization near the subcenters of employment and the economic activity corridors along the main routes of communication. We tested the predictions of the Compact City Approach regarding the influence of the built environment on GHG emissions associated with commuting mobility in the Metropolitan Zone of Mexico Valley (MZMV). Our results indicate that almost all the predictions are fulfilled. Therefore, urban land policies in line with the Compact City Approach that seek to reduce the amount of emissions are fully relevant.

1. Introduction

A large body of scientific literature confirms that human activity has medium and long-term consequences on climate. The planet has limited ability to regulate the carbon cycle. At present, the IPCC predicts a warming of 1.0–3.5 °C by the year 2100 (IPCC, 2014). Despite methodological limitations, the clear majority of climate models indicate that, with increasing temperature, half of the ice caps would melt, which would increase the sea level between 0.5 and 2 m. This would be disastrous for coastal areas, where a sizable percentage of the world's major metropolises are located. More than 180 million people could be affected (Parry et al., 2007). With 25% of total emissions, transportation is one of the main activities that contribute to climate change.[1]

Cities' contribution to total GHG emissions has been measured with disparate results. If we define cities as places that directly emit GHG into the atmosphere, then, despite concentrating more than half the population of the planet, they would only be responsible for between 30% and 40% of total emissions. However, as consumption centers, cities would be responsible for up to 70% of the direct and indirect emissions needed to supply the goods and services consumed in cities (Satterthwaite, 2008; Walraven, 2009; Dodman, 2009; UN-Habitat, 2011).[2] The main sources of GHG emissions are goods manufacturing, the provision of services, food supply, mobility and shelter, but only the latter two are presumably affected by the built environment. According to the Compact City Approach to urban sustainability (Newman and Kenworthy, 1989; Holtzclaw, 1994; Holtzclaw et al., 2002; Ewing and Cervero, 2001; Bürer et al., 2004; Leck, 2006; Litman, 2010; C.E.E., 1990; Jabareen, 2006; Mollay, 2010), a high density and a decentralized but concentrated-polycentric-spatial structure would reduce emissions in housing (apartments expend less energy than single-family dwellings) and mobility (concentration and mixing of functions allows shorter trips, most of them on foot or bicycles, and a greater use of public transport). Empirical evidence mostly supports Compact City predictions on GHG emissions (Glaeser and Kahn, 2010; Brown et al., 2008; Høyer and Holden, 2003; Ryu, 2005; Muñiz et al., 2013).

The main objective of this research is to determine the effect of the built environment on GHG emissions associated with commuting in the Metropolitan Zone of the Mexico Valley (MZMV). To achieve this objective, firstly, GHG emissions were estimated using data from the Origin-Destination Survey, 2007 (ODS-2007) conducted by the National Institute of Statistics, Geography and Informatics (INEGI, in its Spanish acronym) of Mexico. Secondly, different econometric models

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[1] Transport's greenhouse gas (GHG) emissions account for close to 27% of total emissions (IEA, 2008).

[2] The final percentage depends on the minimum size of population for it to be considered a city, as well as the territorial scale used (municipality, metropolitan area, metropolitan region).

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were estimated. The individual amount of GHG emissions is explained by a set of built environment variables referring to urban *spatial form* (density and job ratio), *accessibility* (Employment Potential indicator) and *spatial structure* (distance to the CBD, subcenters, and main roads), as well as other socioeconomic and geographic control variables.

We believe that this research is relevant in part because it focuses on the largest Latin American megalopolis—with 20 million inhabitants—. As was highlighted in Newman and Kenworthy (2015), in recent decades the rate of motorization in cities in developing countries is vertiginous and menacing, because the necessary investment to promote, improve and extend public transportation has not been made. According to Romero-Lankao (2007a, 2007b), this is valid for all Latin American cities and particularly for the Metropolitan Zone of the Mexico Valley, where the primary modes of transport are private vehicles and low-capacity buses. Another of the singularities of the Mexican metropolis is that, contrary to what happens in European and US cities, car usage percentage is higher in the center than at the periphery. These singularities can lead to unexpected correlations which would detract from the validity of the Compact City Approach to urban sustainability.

The structure of the document follows the standard. Section 2 reviews the literature and empirical evidence on the relationship between urban spatial form and structure and GHG emissions; Section 3 introduces the MZMV; Section 4 presents data sources, variables and empirical strategy; Section 5 presents the estimations of per capita GHG emissions; Section 6 discusses the results of the regression models; and finally, Section 7 highlights major findings and policy implications.

2. Empirical Evidence on the Effect of the Built Environment on Commuting GHG Emissions

The impact of the built environment on energy consumption is extensive and dates to the late 1980s and early 1990s. Notably, studies by Webster and Bly (1987), Mogridge (1985), Banister (1992), Prevedouros and Schofer (1991), and especially the work of Newman and Kenworthy (1989, 1999, 2015). Newman and Kenworthy correlate energy consumption in gas and population density. Dense cities consume less energy in mobility than that consumed by sprawling cities. To achieve more efficient mobility, these studies argue for the need to reduce the number of private vehicles in cities and to increase public investment in public transport, particularly in urban rail.

However, the list of studies that have used GHG emissions as an environmental global impact indicator is not large.[3] Among these studies, only a few addresses the impact of the built environment on GHG emissions. One group contains studies that compare GHG emissions in central and dense locations with corresponding emissions in sparse, peripheral places within an urban region (Norman et al., 2006; Van de Weghe and Kennedy, 2007). A second group presents simple correlations between some built-environment measure and GHG emissions or carbon footprint (Ma et al., 2014; Andrews, 2008; Brown et al., 2008). Both studies find global environmental benefits in high density and centrality levels.

One of the methodological limitations of these studies is that they do not consider the possible impact of socioeconomic and geographic variables. This omission could cause an upward bias in the value of the parameter that captures the effect of built-environment variables. A third group of studies presents econometric models with spatially aggregated data (at neighborhood, district or municipality level) where other aspects, such as energy prices or income are included as explanatory variables (Croci et al., 2013; Kennedy et al., 2009; Muñiz and Galindo, 2005). These studies also find an impact of density and centrality variables that is statistically significant but lower than that obtained in the first and second group of studies. Although the methodology used in this third group of studies improves on the first two, it suffers from the characteristic limitations of spatially aggregated models. It is people, not territories, who directly or indirectly emit GHG gases into the atmosphere, so it is preferable to work with individual data. The fourth group of studies uses individual data regarding socioeconomic conditions and built-environment indicators (Ryu, 2005). Once again, empirical evidence corroborates the existence of environmental benefits associated with high density and centrality levels.

Both aggregated models and individual data models could obtain biased parameters due to endogeneity issues (Cao et al., 2009). For models with individual data, the main problem addressed by literature is "self-selection". If individuals choose their place of residence on the basis of their preferences for mobility, failure to consider this information can skew the values of built-environment variables. The most common solutions are: a) select a sample of population with little ability to choose their place of residence (such as young people who work and live with their parents) (Dujardin et al., 2008; O'Reagan and Quigley, 1998); or b) include a variable that captures the preferences of individuals regarding mobility, and translate this information in the regression model. A fifth group of studies estimates the effect of the built environment on GHG emissions controlling for endogeneity (Høyer and Holden, 2003; Muñiz et al., 2013). The results of both studies are mixed. While in Høyer and Holden (2003) the greater the size of the city being considered, the lesser is the effect exerted by the variable of urban spatial form used (density), in Muñiz et al. (2013), both variables—density and distance to the CBD—exert the expected effect, even when the emissions associated with the holiday period are added. In short, all the above research is mostly favorable to Compact City Approach predictions.

The analysis of the relationship between cities and climate change should not be limited to mitigation strategies, but should also include the impact of climate change on cities and how they can adapt to such change through measures that reduce their vulnerability and increase their resilience (Hunt and Watkiss, 2011; IPCC, 2014: Bulkeley, 2010). Much of the empirical literature available has addressed only mitigation, not adaptation.[4] However, it is worth recalling that the impact of climate change on cities will foreseeably affect the provision of food and water, energy consumption and transport. These effects will not only be environmental; they will also be of an economic nature (Romero-Lankao and Dodman, 2011; Hunt and Watkiss, 2011; IPCC, 2014).

The literature on adaptation (Muller, 2007; Brown et al., 2012) and resilience (Willems et al., 2012; Romero-Lankao, 2007a, 2007b, 2010; Hardoy and Pandiella, 2009; Hardoy and Romero-Lankao, 2011) has increased significantly over the last decade. The study of the impact of climate change on cities has also been approached from the perspective of ecological footprints; that is, such studies keep in mind the cascading effects between inputs and consumptions in a context in which resources come from a globally dispersed surface far higher than that of the city itself and its bioregion (Brown et al., 2012). On the other hand, several studies point out how the impact of climate change on the city dwelling population depends on the wealth of this population. Cities with a high percentage of low-income families are therefore particularly vulnerable (Mitlin and Satterthwaite, 2013, Dodman, 2009, Hardoy and Pandiella, 2009, Romero-Lankao and Dodman, 2011).

The literature on vulnerability and adaptation to climate change has

[3] The most commonly used global environmental impact indicators are fuel consumption, energy used, percentage of trips by car, or km traveled by car (Newman and Kenworthy, 1989, 1999, 2015; Holtzclaw et al., 2002; Ewing et al., 2007; Kenworthy and Laube, 2005; Leck, 2006). The Newman and Kenworthy (1989) graph, in which population density is correlated with the consumption of gasoline in different cities throughout the world, is the most recognizable figure in the lengthy debate.

[4] In Latin America, the literature on the adaptation and resilience of cities is not extensive. However, certain contributions are noteworthy, as are public initiatives to carry out various plans whose objective is to reduce vulnerability and increase the resilience of cities (Hardoy and Romero-Lankao, 2011; IPCC, 2014; Carcellar et al., 2011).