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Individual transport emissions and the built environment: A structural equation modelling approach

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ABSTRACT

Increasing CO_2 emissions from the transport sector have raised substantial concerns among researchers and policy makers. This research examines the impact of the built environment on individual transport emissions through two mediate variables, vehicle usage and vehicle type choice, within a structural equation modelling (SEM) framework. We find that new-urbanism-type built environment characteristics, including high density, mixed land use, good connectivity, and easy access to public transport systems help reduce transport CO_2 emissions. Such mitigating effect is achieved largely through the reduced vehicle miles travelled (VMT) and is enhanced slightly by the more efficient vehicles owned by individuals living in denser and more diverse neighborhoods, all else being equal. Our research findings provide some new evidence that supports land use policies as an effective strategy to reduce transport CO_2 emissions.

1. Introduction

Transport has been a major contributor to the dramatic rise of carbon emissions worldwide (Dulal et al., 2011). According to the data in 2011, CO_2 generated from transport has increased from 4605 million tonnes in 2009 to 7001 million tonnes in 2011, accounting for approximately 22% of global CO_2 emissions (IEA, 2013). The rapid growth in transport emissions was mainly driven by emissions on the road, which increased by 52% since 1990 (IEA, 2013). The International Energy Agency (IEA) expects global transport-related CO_2 emissions to increase by 50% by 2030, and by more than 80% by 2050 (IEA, 2009). Approaches to reducing carbon emissions from transport thus have received considerable attention. In addition to technology innovations to improve the energy efficiency of vehicles and economic approaches to increase the cost of driving, land use control policies that aim to reduce vehicle dependence by changing the built environment have been widely considered an effective means to reduce transport emissions.

The amount of CO_2 emissions generated from urban transport is determined by multiple factors, such as vehicle usage, vehicle efficiency, and fuel type (Schipper et al., 2000). The dramatic increase in vehicle usage, often measured in vehicle miles travelled (VMT), is suggested to be one of the most important factors affecting transport emissions (Cervero and Murakami, 2010; Millard-Ball and Schipper, 2011). This has sparked numerous studies into the influence of the built environment on VMT, especially in the context of global warming (Grazi et al., 2008; Aditjandra et al., 2013). However, VMT is not equivalent to CO_2 emissions due to the substantial heterogeneity in vehicle emission levels. For example, the Tesla Model

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S is claimed to be a zero emission vehicle while the CO_2 emissions from a Sport Utility Vehicle (SUV) could be hundreds of grams of CO_2 per kilometer travelled. Ignoring the vehicle type effect might yield significant bias in transport CO_2 emission studies. In the meantime, many existing studies targeting directly on transport CO_2 emissions use an aggregate approach to investigate the relationship between the built environment and transport energy consumption or emissions at the neighborhood, city, or country levels (e.g. Newman and Kenworthy, 1989; Lindsey et al., 2011). Such studies have provided useful insights into transport emission reduction by revealing the general trends in the land use and transport interactions. However, statistical analyses based on aggregate measures generally ignore the individual heterogeneity within a specific area and do not allow for an exploration of the underlying mechanisms by which the built environment may influence individual decisions.

Our study aims to fill the gaps by discerning the complex interactions among the various factors that could influence individual transport emissions using Structural Equation Modelling (SEM). Specifically, our study examines the effects of the built environment and socio-demographic characteristics on individual transport CO_2 emissions through two mediate variables – vehicle usage and vehicle type choice. We find that new-urbanism-type built environment characteristics including high density, mixed land use, good connectivity, and easy access to public transport systems help reduce transport CO_2 emissions. Such mitigating effect is achieved largely through the reduced VMT and is enhanced slightly through the more efficient vehicles owned by individuals living in denser and more diverse neighborhoods, all else being equal. The SEM techniques allow researchers to decompose the total effect of one variable on another into direct effect and indirect effect through other intermediate variables. We find that by considering all the direct and indirect effects, the built environment has a larger impact on VMT and a smaller impact on vehicle type choice compared to that of individual socio-demographic characteristics. Overall, the built environment affects transport emissions to a larger extent than that of individual socioeconomic and demographic attributes. Our research findings provide some new evidence to support the design of policies aiming to relieve transport emissions.

The remainder of this paper is structured as follows. Section 2 briefly reviews the research on the relationship between land use and transport CO_2 emissions. Section 3 introduces the study area, methodology, data sets and variables in the empirical analysis. Section 4 presents the main empirical results. The last section summarizes research findings and proposes future research directions.

2. Literature review

The connection between the built environment, socio-demographic attributes and transport CO_2 emissions has been widely investigated in transportation research. In this section, we review the related literature to provide a proper context for our study.

2.1. The impact of the built environment on vehicle usage and vehicle type choice

In the transportation field, a large number of studies have focused on the impact of the built environment on vehicle usage often measured in VMT. The underlying assumption is that given the stable improvement of vehicle technology, the less VMT generated, the less carbon will be released from automobiles. The theoretical foundation for the built environment effect on VMT can be found in the theory of utilitarian travel demand (Lancaster, 1957). This theory postulates that travelers do not derive their utilities from the trips per se, but from the need to engage in activities located at different places. Therefore, land use configuration could affect travel patterns (Boarnet and Crane, 2001). In general, new-urbanism-type built environment characteristics such as high density, mixed land use, good connectivity, and easy access to public transport are expected to encourage travelers to shift from driving to walking, bicycling, or taking public transportation (Cervero, 2002; Brownstone, 2008; Cao et al., 2009). For example, using data from 370 urbanized areas in the US, Cervero and Murakami (2010) found that denser urban settings with better retail and transit accessibility lead to a reduction in individual VMT. Using a difference-in-differences analysis, Zhu and Diao (2016) found that the inauguration of a new urban rail transit line in Singapore has reduced the levels of car dependence in wealthy households living in the proximity of new rail stations. Sun et al. (2009) compared the influence of the built environment and a household's lifecycle stages on vehicle usage. They found that the built environment has a larger explanatory power on the differences in the share of automobile trips, whereas the lifecycle stages explain the number of trips being made. Diao and Ferreira (2014) indicated that built environment factors not only play an important role in explaining the intra-urban variation of VMT in Metro Boston, but may also be underestimated by previous studies that use more aggregate built environment measures.

However, studies focusing on vehicle usage generally ignore the role of vehicle type choice in individual transport CO_2 emissions, which could bring significant biases to transport emission research due to the substantial heterogeneity in vehicle emission levels measured in grams of CO_2 per mile travelled.[1] Researchers have found that the built environment can also influence transport CO_2 emissions through individual vehicle type choice (Brownstone and Golob, 2009; Lindsey et al., 2011;

[1] In European countries, vehicle emissions have been increasingly heavily regulated, which could reduce the variation of emission factors among vehicles that are approved by the same standard.