Transportation Research Part D 57 (2017) 363–377

Contents lists available at ScienceDirect

Transportation Research Part D

journal homepage: www.elsevier.com/locate/trd

Does urbanization lead to less energy use on road transport? Evidence from municipalities in Norway

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ARTICLE INFO

Keywords:
Dwelling type
Norway
Road energy use
Urban density
Urbanization

ABSTRACT

The relationship between urbanization, energy use, and CO_2 emissions has been extensively studied in recent years, however little attention paid to the differences in urban forms. Previous studies implicitly assume that the urban form is homogenous across different urban areas. Such an assumption is questionable as urban form can have many different facets. This paper investigates the effects of urbanization on the road transport energy use by considering different urban forms from a dataset of 386 Norwegian municipalities from 2006 to 2009. Using the Stochastic Impacts by Regression on Population, Affluence, and Technology (STIRPAT) model with an energy use identity equation, the main findings (1) confirm the well-established result that urban density has a negative and significant influence on road transport energy use, and (2) demonstrate that the effect of urbanization partly depends on the level of urban density. These results imply that additional increases in urbanization in dense areas yield greater decreases in road transport energy use per capita. Additional findings posit that (3) there is a non-linear (quadratic) relationship between road energy use per capita and urban population. This implies that an increase in total municipality population over a specific turning point can result in a decrease in road energy use per capita. However, (4) the ratio of urban residential buildings with private gardens has a negative and significant influence on road transport energy use. This implies that there may be a trade-off between compact and sprawl city development strategies, highlighting that sustainable energy use requires further investigation.

1. Introduction

Around 54% of the world's population lives in urban areas. This is projected to increase to 66% by 2050 with an extra 2.5 billion inhabitants occupying urban spaces (UN, 2014). Such rapid urbanization has generated a multitude of problems and opportunities for not only the economy, but also the environment as urban transport accounts for more than one-fifth of global carbon dioxide emissions (Liddle, 2013). The growth rate of transport energy use – three quarters of which consumed on the road – is projected to increase 2% annually (Saboori et al., 2014). This means that good understandings of road energy use are required to provide insight into the development of more sustainable cities, although the connections between urbanization and environmental impacts are not

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http://dx.doi.org/10.1016/j.trd.2017.09.021

clear (Brian C O'Neill et al., 2012; Ergas et al., 2016; Li and Lin, 2015; Liddle, 2014; Ponce De Leon Barido and Marshall, 2014; Poumanyvong and Kaneko, 2010; Ramana Gudipudi and Kropp, 2016).

Some scholars claim that urbanization has positive environmental impacts by decreasing road energy use (Gudipudi et al., 2016; Liddle, 2013) while others claim it generates more emissions (Poumanyvonga et al., 2012). These conflicting results make the real effects of urbanization on the environment inconclusive (Poumanyvonga et al., 2012), leading to the need for more studies regarding the potential detrimental effects of urbanization on the environment. Such disagreements in the extant literature may be due to the quality of data used, as well as the deployment of different methodologies. Specifically, the failure to consider urban form differences could be one reason as most studies implicitly assume that it is homogenous across different areas. This is questionable due to its multiple facets (e.g., urban area, urban density, residential dwelling spatial structure) across countries and geographical regions. In addition, many recent empirical studies have found that some urban form variables (e.g., urban area, residential density, housing sizes and types, urban structure) can have significant impacts on environment (i.e., carbon emission, energy use) (Boyko and Cooper, 2011; Fang et al., 2015; Lee and Lee, 2014; Norman et al., 2006; Perkins et al., 2009; Reingewertz, 2012; Yang et al., 2015; Yin et al., 2015). Therefore, further studies with careful considerations of the different urban forms become imperative. Specifically, there have been few studies that examine urbanized area level spatial form impact on the environment due to the lack of appropriate measures (Lee and Lee, 2014). As such, the objective of this paper is to investigate the effects of urbanization on road transport energy use. This is achieved by considering a variety of urban forms taken from available municipality level information on urban residential building spatial structures across 386 Norwegian municipalities from 2006 to 2009. Based on the cross section analysis, the findings demonstrate that the effect of urbanization partly depends on the level of urban density, implying that additional increases in urbanization of already densely populated areas yield greater decreases in road transport energy use per capita.

The paper is structured as follows. First, the related literature is explained. Second, the model, data, and empirical strategy are presented. Third, the main estimation results and discussions are given. Finally, the conclusions are offered.

2. Literature review

A popular framework used to distinguish the impact of population and income on the environment is stochastic impacts by regression on population, affluence, and technology (STIRPAT). This was developed by Dietz and Rosa (1997) and exhibited in the following Eq. (2.1) where *I* is the environmental impact, *P* is population, *A* is affluence, consumption per capita or income per capita, and *T* is the technology or impact per unit of consumption. The subscript i denotes cross sectional units; a, b, c, and d are the parameters to be estimated; and e is the error term in the regression model:

$$I = aP_i^b A_i^c T_i^d e_i \tag{2.1}$$

Thus, Eq. (2.1) leads to the following linear log-function (2.2):

$$\ln(I_i) = a + b\ln P_i + c\ln A_i + d\ln T_i + e_i \tag{2.2}$$

Researchers applying the STIRPAT frame to carbon emissions or energy use typically include data on population, income, urbanization level, urban density, and age compositions in their analyses, summarized in the Appendix A1 (Boyko and Cooper, 2011; Fan et al., 2006; Hossain, 2011; Liddle, 2004; Liddle and Lung, 2010; Martínez-Zarzoso et al., 2007; Martínez-Zarzoso and Maruotti, 2011; Menz and Welsch, 2012; Norman et al., 2006; Perkins et al., 2009; Poumanyvong and Kaneko, 2010; Poumanyvonga et al., 2012; Yang et al., 2015; Zhu and Peng, 2012). The common feature in these studies is the lack of information on the urban form which may be ascribed to the deficiency of appropriate measures of urban area level spatial structure (Lee and Lee, 2014) as well as the limited variables in the STIRPAT framework. Indeed, many variables describing urban form (e.g., area, share of residential building type, urban density) are identified as important driving forces with environmental impacts (Boyko and Cooper, 2011; Norman et al., 2006; Perkins et al., 2009). Further, there are two arguments supporting the idea of controlling the ratio of residential building type in a municipality space area from empirical observations. First, it is reasonable to believe that distance from city center is a determinant factor of road transport energy use. According to urban theory, the density of residential housing has a negative relationship with the distance to the city center (Gaigné et al., 2012). Therefore, it is hypothesized that more compact urban areas lead to less transport energy use. Second, it has been empirically verified that age-structure plays a critical role in housing location decisions (Lee et al., 2016). At the same time, there is the implicit idea of housing hierarchy in which low- and moderate-income tenants move into more comfortable quarters while the wealthier tenants save to become first-time homebuyers who thereafter trade up to bigger and better homes (Morrow-Jones and Wenning, 2005). It therefore seems appropriate to assume that the density of housing has a negative connection with age structure and that the omission of these variables, given that they have significant explanatory power, may lead to different estimation results. Thus, by introducing the variables of urban building type, urban area (or urban settlement area), and urban density into the equation, the estimations in this paper may provide greater understanding of the factors that influence road energy use in geographical spaces.