Transport Policy 61 (2018) 60–74

Contents lists available at ScienceDirect

Transport Policy

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

Driving factors of GHG emissions in the EU transport activity

Lidia Andrés, Emilio Padilla *

Department of Applied Economics, Universidad Autónoma de Barcelona, Campus de Bellaterra, 08193 Cerdanyola del Vallès, Spain

ARTICLE INFO

Keywords:
Greenhouse gas emissions
STIRPAT model
Transport activity

ABSTRACT

This research analyzes the importance of population, economic activity, transport volume and structural characteristics of transport activity—in terms of transport energy intensity, of transport modes' share and of energy sources' mix—as driving factors of greenhouse gas emissions in transport activity in the EU-28 during the period 1990–2014. The analysis is based on the STIRPAT model, which is broadened to investigate in depth the impact on transport emissions of changes in the transport activity and in the whole economy. Using panel data econometric techniques, the significance of each factor and the impact of its change on emissions are identified. A better knowledge of the key driving forces is crucial for implementing policies focused on successfully reducing emissions in transport activity. The results allow a preliminary assessment of the potential effectiveness of the 2011 Transport White Paper measures aimed at cutting transport emissions.

1. Introduction

Greenhouse gas emissions decreased by 22.4% in the EU-28 between 1990 and 2014. All the source sectors contributed to this reduction with one exception, the transport sector. This sector showed completely different behavior, as its emissions increased by 13.3% during the period, from 784,507.0 to 889,065.5 thousand tonnes of CO_2 equivalent (Eurostat, 2016).[1] Consequently, the contribution of the transport sector has increased considerably since 1990, amounting to 20.8% of the overall greenhouse gas emissions in 2014. The transport sector is currently the second most important source of emissions in the EU-28 after the energy sector.

The upward trend in emissions in the EU-28 transport sector is related to a 24.2% rise in its energy consumption over the period, reaching a total of 352,936.3 thousand tonnes of oil equivalent in 2014, which amounted to 33.2% of the total final energy consumption. Between 1990 and 2007, in a scenario of high economic growth, the energy consumption in the EU-28 transport sector increased by 34.8% and its emissions by 25.9%, whereas, between 2007 and 2014, a period of economic downturn and lower economic growth, the energy consumption of the transport sector decreased by 7.9% and its emissions by 10.0%. These figures show the difficulty of mitigating greenhouse gas emissions in the transport sector, as they are the result of the level of energy consumption and the mix of energy sources used in transportation (see Table 1).

An in-depth study of the trend of greenhouse gas emissions in the EU transport activity in the last decades is necessary to assess the mitigation policies. This paper focuses on analyzing the driving factors of greenhouse gas emissions in the EU transport activity over the period 1990–2014 and on quantifying the impact of a change in any of them on such emissions using a new, extended version of the STIRPAT model. Moreover, panel data econometrics is employed to quantify the impact of the different factors. This paper, in a novel way, extends the application of the STIRPAT model to the analysis of greenhouse gas emissions in transport activity by accounting for the structural characteristics of the sector. In particular, our model includes population, economic activity, transport volume and structural characteristics—taking into account the energy intensity of the activity, the share of each mode of transport in the total activity and the share of each source of energy in the total transport energy consumption. The objective is to highlight that the effect of the activity on its emissions relies not only on the volume of transport but also on its characteristics, i.e., energy intensity, modal structure and energy source mix. As pointed out by Grazi and van den Bergh (2008), the results of the environmental policies aimed at reducing emissions in the transport sector depend on their effects on the modal split, energy efficiency, fuel type used and transport volume (passenger-kilometers or tonne-kilometers). Therefore, both the volume and the structural characteristics of the transport sector are important in explaining the change in its emissions and in designing more accurate policies. Additionally, it

* Corresponding author.
E-mail addresses: lidia.andres@uab.es (L. Andrés), emilio.padilla@uab.es (E. Padilla).

[1] The seven greenhouse gases considered by Eurostat data are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). The relevant greenhouse gases in the case of transport are CO_2, CH_4 and HFCs.

https://doi.org/10.1016/j.tranpol.2017.10.008
Received 15 March 2017; Received in revised form 15 October 2017; Accepted 16 October 2017

Table 1
Energy consumption in the EU-28 transport sector, total activity and classification by energy sources (thousand TOE): 1990–2014.

	Energy consumption			Share	
	1990	2014	Total change (%)	1990	2014
Total activity	284,171.2	352,936.4	24.2%	100.0%	100.0%
Sources of energy					
Solid fuels	213.5	8.6	−96.0%	0.1%	0.0%
Petroleum products	278,144.5	330,493.1	18.8%	97.9%	93.6%
Gas	338.7	2,955.7	772.7%	0.1%	0.8%
Renewable energies	18.8	14,141.3	75,119.7%	0.0%	4.0%
Electrical energy	5,455.7	5,337.7	−2.2%	1.9%	1.5%

Source: Prepared by the authors with data from Eurostat (2016)

is relevant to consider whether there are any significant differences between regions. A further contribution of this paper is that it performs the analysis for the EU as a whole as well as differentiating by regions (western EU and eastern EU), considering their differentiated economic structures and levels of development. Finally, this paper differs from previous research, as it focuses the analysis on the greenhouse gas emissions of the transport sector instead of only the CO_2 emissions. Although CO_2 is the most important greenhouse gas, other greenhouse gases, CH_4 and N_2O, are also emitted during fuel combustion.[2] In addition, transport activities also emit HFC gases resulting from vehicle air conditioning and refrigerated transport. It is, therefore, necessary to take into account all the greenhouses gases emitted by the activity in order to analyze the overall impact of the activity in global warming. In addition, this would eventually avoid erroneous interpretations in the cases that CO_2 emissions declined at the same time that the emissions of the other three gases increased.

The main purpose of the analysis is to inform the design of environmental policies focused on mitigating environmental impacts, besides promoting efficient energy use and energy savings in the transport sector. Using the results of this analysis, our research will also specifically contribute to assessing the potential effectiveness of the environmental strategies proposed in the 2011 Transport White Paper (European Commission, 2011), the aims of which include a 60% reduction in the transport sector emissions by 2050 in relation to 1990.

The rest of the paper is structured as follows. Section 2 provides a review of the literature. Section 3 describes the data and the methodologies employed. Section 4 presents the results and the discussion. Section 5 summarizes and concludes the paper.

2. Literature review on the determinants of transport activity emissions

The role of the transport activity in greenhouse gas emissions has been studied broadly. Part of this literature is based on the IPAT identity (Ehlrich and Holdren, 1971, 1972), which is widely used as a basis for analyzing the impact of economic activity on the environment. Founded on ecological principles (York et al., 2003), it states that the environmental impact (I) is the product of population (P), affluence (A) and technology (T).

In particular, most of the investigations that study the driving factors of transport emissions are based on the IPAT identity or, alternatively, on the Kaya identity (Kaya, 1989) or the ASIF methodology (IEA, 1997), which are expanded versions of the IPAT identity. These studies use index decomposition analysis to obtain detailed information on the importance of the different driving factors explaining changes in environmental pressure over time. In this line of research, there are works focused on studying the driving factors of the transport sector emissions as a whole. For example, the investigations reported by Mazzarino (2000), Timilsina and Shrestha (2009), Guo et al. (2014) and Fan and Lei (2016), based on the IPAT identity, find that population, economic activity and transport energy intensity are the main driving forces of transport emissions.[3] Likewise, there are works addressing the specific driving factors of the emissions of passenger and freight transport activities. Examples of these are the investigations conducted by Scholl et al. (1996), Lakshmanan and Han (1997), Steenhof et al. (2006) and M'raihi et al. (2015). These studies are mostly based on the ASIF equation and find that the transport volume, modal share, transport energy intensity and energy mix[4] are the main driving factors of emissions in these activities. Other studies investigate the driving factors of the emissions of a specific mode of transport, for instance those by Andreoni and Galmarini (2012) and Sobrino and Monzon (2014). There are even very concrete studies, such as the work by Kwon (2005) and Papagiannaki and Diakoulaki (2009), focused on finding the driving factors of the cars' emissions. These last investigations are based on the IPAT or Kaya identities and find that the main driving factors are economic activity and/or transport volume and transport energy intensity. However, all these studies, which, in essence, are based on the IPAT identity, present the same two limitations. First, it is an accounting equation and does not allow hypothesis testing, and, second, it assumes that the functional relationship between factors is proportional (York et al., 2003).

A different line of research, also based on the IPAT identity, is developed by Dietz and Rosa (1994, 1997). They propose an alternative model, the STIRPAT model (the Stochastic Impact by Regression on Population, Affluence and Technology model), which is a reformulation of the IPAT identity into a stochastic model that overcomes its limitations, as it allows estimation and hypothesis testing using econometric techniques. Various recent investigations employ the STIRPAT model to analyze the environmental impact of transport activity: Zhang and Nian (2013) and Xu and Lin (2015, 2016) are examples (Table 2).

Another different line of research is the literature focused on analyzing the proper design of environmental policies aimed at reducing transport emissions. The recent investigations of Tight et al. (2005), Hickman and Banister (2007), Hull (2008), Hickman et al. (2010), Banister and Hickman (2013) and Eliasson and Proost (2015)are some examples. Other studies focused on traffic flow models and simulation models and made significant contributions to understand the impacts of different variables on emissions; some examples are the works of Yu (1998), Zhu (2013) and Tang et al. (2015, 2017).

This research provides various contributions to the previous literature on the analysis of transport emissions. First, it makes a methodological contribution, as it extends the STIRPAT model by incorporating the structural composition of transportation where, besides transport energy intensity, modal share and energy mix are taken into account.

[2] According to IPCC (Kahn Ribeiro et al., 2007), CO_2 emissions account for around 96%, CH_4 emissions account for 0.1%–0.3% of total transport emissions, whereas N_20 emissions account for 2.0%–2.8% (based on US, Japan and EU data only).

[3] The investigation of Mazzarino (2000) does not identify population as a main driving factor.

[4] The study by Lakshmanan and Han (1997) does not include the energy mix in the analysis. As regards M'raihi et al. (2015), they point out to economic growth as the main driving factor of transport emissions.