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Ex-post decomposition analysis of passenger car energy demand and associated CO_2 emissions

Emer R. Dennehy[a,b,*], Brian P. Ó Gallachóir[a,c]

[a] Energy Policy and Modelling Group, MaREI Centre, Environmental Research Institute (ERI), University College Cork, Lee Road, Cork T23 XE10, Ireland
[b] Sustainable Energy Authority of Ireland (SEAI), Building 2100 Cork Airport Business Park, County Cork T12 KV8R, Ireland
[c] School of Engineering, University College Cork, Cork, Ireland

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ABSTRACT

This paper investigates, quantifies and ranks the factors influencing passenger cars energy demand and emissions. A vehicle stock-model approach is used for an ex-post decomposition analysis, based on administrative data, examining the impact seven underlying factors driving energy demand. The impact of methodological choice and model disaggregation are also explored. In light of the 2015 vehicle emissions scandal, the paper quantifies the difference between manufacturer-test vehicle performance and real world or "on-road" performance for a national stock model and determines the relative impact on passenger cars energy consumption. When examining the technical performance improvement, the choice of metric can lead to a distortion of 2.2 percentage points (14% overestimate) in the quantification of the efficiency improvement of the vehicle stock. The analysis pays particular attention to the influence of fuel or technology switching – which is often quoted as a factor influencing energy use and emissions but rarely quantified. Even when using litres per hundred-kilometre gasoline equivalent to measure the performance improvement, changes in the makeup of the stock can lead to distortion in the efficiency measure. The results of a full decomposition analysis highlight that technical performance improvements (energy efficiency improvements for the purpose of this paper), will not provide significant energy and emission savings when the impact on-road consumption is included. The paper concludes that technology switching in conjunction with policies targeting ownership and usage are the most effective measures to control passenger car energy consumption and associated CO_2 emissions.

1. Introduction

The International Energy Agency (IEA) estimates that the transport sector is responsible for 22% of energy-related carbon dioxide (CO_2) emissions (IEA, 2015a). Transport accounts for almost 19% of all energy[1] globally and its share of total final energy demand is 28% globally, with the figure increasing to 33% for OECD countries (IEA, 2015b). The transport sector has a significant dependence on oil, with a share of 94% of all global transport energy use in 2015 – a reliance that has not changed since the 1970s (IEA, 2016). The expectation is that the share of transport energy demand and associated emissions will grow in developing economies in

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* Corresponding author at: Sustainable Energy Authority of Ireland (SEAI), Building 2100 Cork Airport Business Park, County Cork T12 KV8R, Ireland.
E-mail addresses: emer.dennehy@seai.ie (E.R. Dennehy), b.ogallachoir@ucc.ie (B.P. Ó Gallachóir).

[1] 19% of total primary energy which is defined as the total requirement of all uses of energy including energy used to transform one energy form to another (e.g. burning fossil fuels to generate electricity) and energy used by the final consumer.

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conjunction with economic growth. In the absence of diversification away from petroleum products, there are high expectations from energy efficiency in the transport sector.

Energy efficiency in transport can be achieved through a number of approaches. These approaches include technical energy efficiency improvement (for example where the fuel economy or energy or emissions performance [gCO2/km] of the vehicle stock is improved), behavioural improvements (such as eco-driving and vehicle sharing), or policy measures, such as influencing vehicle purchasing trends, modal shift, logistics management or changing speed limits to name but a few.

The methods used to measure energy efficiency in transport give further insights into what is considered energy efficiency in the transport sector, but it is not a trivial exercise to quantify transport energy efficiency savings. Data limitations often hinder the possible indicators or metrics that can be calculated. Some improvements are extremely difficult to quantify due to a lack of data (Schipper, 2009) or lack of quality data (Schipper, 2011). In addition, behavioural changes cannot be counted on as long-term energy savings due to rebound effects (Schipper and Grubb, 2000; Greening, 2004; Biying et al., 2013).

Passenger cars[2] have been the focus of a lot of policy changes in many countries in recent years.[3] Fuel economy and emissions standards are among the most commonly advised and implemented policies to improve the energy efficiency (technical performance) of private transport vehicles (EU, 2009a; IEA, 2015c). A problem with manufacturer fuel consumption and/or emissions ratings are that they are based on laboratory test fuel consumption values, which are very different to the real world vehicle performance or 'on-road'[4] performance. This was a known problem even before the revelations of the recent (2015) vehicle emissions scandals (Schipper et al., 1993; Zachariadis, 2006) but it has been suspected of widening in recent years (Tietge et al., 2015; GFEI, 2016; Tietge et al., 2017).

Following an investigation into car manufacturer Volkswagen, in light of their admission to using cheat software to lower the nitric oxide emission (NO_x) from vehicles during USA emissions testing, the company issued a statement on November 3rd 2015 that vehicle CO_2 emissions and thus vehicle fuel consumption were also underestimated by the company (Volkswagen, 2015). This legitimately raised concerns about the validity of all vehicle emission and fuel efficiency labels. Indeed since November 2015 there have been further questions raised about the validity of more vehicle manufacturers' fuel and emissions performance (gCO2/km) values (Sorokanich, 2016; Fontaras et al., 2017). The impact of real world fuel consumption as opposed to laboratory or 'on-road' consumption and its relative significance in influencing overall energy consumption is also quantified in this paper.

Ireland is an interesting case study for this paper due to recent and projected strong energy demand growth in transport and ambitious emissions targets. Within the European Union (EU) a CO_2 based 'Cap and Trade' system, known as the Emissions Trading Scheme (ETS), has been in place since 2005. The ETS scheme includes electricity generating power stations, large-scale industrial plants, and, since 2012, aviation sector. All other greenhouse-gas emitting sources are collectively termed non-ETS emissions sources. Non-ETS emissions sources include energy consumption in the residential, transport, agriculture and waste sectors, as well as small businesses/industry. Also included are non-energy related agriculture and waste disposal emissions. The EU Effort Sharing Decision (Decision No 406/2009/EC) aims to limit EU non-ETS emissions and stipulates that Ireland must achieve a 20% reduction in non-ETS emissions from their 2005 levels by 2020 (EU, 2009b).

Transport emissions account for almost a quarter of Ireland's total Greenhouse Gas emissions, more than a third of Ireland's energy-related CO_2 emissions and 60% of energy related non-ETS CO_2 emissions. Transport energy-related emissions in Ireland fell by only 0.5% per annum between 2010 and 2014, and actually grew by almost 4% in 2014 and 5.9% in 2015, indicating the scale of the challenge in the transport sector (SEAI, 2016). In Ireland passenger cars have historically dominated in the road vehicle fleet, representing 78% of the road vehicle fleet in 1995 and still at 77% in 2015 and the number of passenger cars in the Irish fleet grew doubled over the period 1995 to 2015 (Department of transport, 2016).

A recent decomposition analysis of passenger transport in Ireland was based on passenger kilometres and recommended; "Further research on passenger transport should seek to fill gaps in knowledge towards a better understanding of the causal factors underlying the identified trends in each mode" (Jennings et al., 2013). This paper aims to improve that understanding for passenger cars, based on a detailed stock model approach that facilitates the analysis of more causal factors. It is also interesting to base the decomposition analysis on a technology specific indicator, in this case litres per hundred kilometre (l/100 km), rather than an activity-based indictor such as energy use per passenger kilometre. Unlike the technology-based indicator, which is independent of activity, depending on the disaggregation of the model used in the analysis the activity-based indicator can change significantly. A derived or calculated activity-based indicator is also more inclined to display fluctuating trends, not least when the denominator varies with different levels of disaggregation.

The paper is structured as follows; Section 2 is a theoretical review, which frames the context and content of the methodological approach. The starting point in the efficiency indicators section (Section 2.1) which examines the influence of the choice of efficiency or technical performance metric and fuel switching (technology switching) on a the quantification of efficiency in passenger cars. Improving the estimates for on-road fuel efficiency at a national or economy wide level are also considered in this section. Greater disaggregation using a detailed stock model is proposed in Section 2.2. Identity equations for both energy and emissions using readily available administrative data are proposed to facilitate a detailed decomposition analysis. The choice of decomposition analysis methodology is discussed in Section 2.3.

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[2] Vehicles taxed for the purpose of private use, includes company cars and sports utility vehicles (SUVs).

[3] Examples of emissions based vehicles taxation can be found in the International Energy Agency Policies and Measures database (PAMS) database. (IEA, various years).

[4] The terms real world efficiency or on-road efficiency are used interchangeably in this paper and reference to the actual efficiency (l/100 km or gCO2/km) of passenger cars when driven outdoors as opposed to in a laboratory test conditions.