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Rebound effects in UK road freight transport

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ABSTRACT

This paper analyses aggregate time-series data to estimate the direct rebound effect in UK road freight over the period 1970–2014. We investigate 25 different model specifications, conduct a comprehensive set of diagnostic tests to evaluate the robustness of these specifications and estimate the rebound effect using three different elasticities. Using the mean of the statistically significant estimates from these specifications, we estimate a direct rebound effect of 61% - which is larger than previous estimates in the literature and almost twice as large as the consensus estimate of direct rebound effects in road passenger transport. Using the mean of the estimates from our most robust models, we estimate a slightly lower direct rebound effect of 49%. Our estimates are fairly consistent between different model specifications and different metrics, although individual estimates range from 21% to 137%. We also find that an increasing proportion of UK road freight is being undertaken by foreign registered vehicles, and that increases in the vehicle weight limits have encouraged more freight activity. We highlight the significant limitations imposed by the use of aggregate time series data and recommend that further studies in this area employ data from vehicle use surveys.

1. Introduction

In 2015, freight transport accounted for 6% of global energy consumption and one third of transport energy consumption (IEA, 2016). Although road transport by heavy goods vehicle (HGV) accounted for only around one quarter of global freight activity (in tonne kilometres), it was responsible for nearly three quarters of energy use for freight transport and around one quarter of energy use for road transport. Energy use for freight transport is growing faster than for passenger transport and the scope for substituting towards low carbon fuels is limited. But despite this, freight transport tends to be neglected by both researchers and policymakers.

Historically, freight activity has grown in line with economic activity, along with the associated energy consumption. However, in the past three decades there has been some decoupling of freight activity from GDP in OECD countries, partly a result of economic restructuring and the outsourcing of manufacturing to emerging economies (McKinnon, 2007; Tapio, 2005). While increased consumption of material goods tends to increase freight activity, the relationship between the two is mediated by a range of factors, several of which have undergone major changes in recent years. These include, for example, shifts towards lighter commodities, wider sourcing of products, the growth of just-in-time distribution, increases in packaging volume and greater concentration of manufacturing and stockholding (Lehtonen, 2008). In turn, energy consumption for road freight has been affected by additional changes in logistics, driving patterns, road congestion, the amount of empty running and the average size, fuel efficiency and load factor of HGVs (Sorrell et al., 2009, 2012).

With fuel costs accounting for up to one third of operating costs (Freight Transport Association, 2017), freight operators have a strong economic incentive to minimise fuel consumption. But while more fuel-efficient vehicles (i.e. less fuel use per vehicle

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kilometre) can contribute towards this end, operational factors such as the average size of vehicles (maximum loaded weight) and the average load factor of those vehicles (ratio of average to maximum loaded weight) tend to be more important (Sorrell et al., 2009, 2012). In the case of UK road freight, average fuel use per tonne kilometre has fallen over the last 30 years while fuel use per vehicle kilometre has remained relatively static (Sorrell et al., 2012). With the exception of changes in road fuel duty, public policy measures to reduce carbon emissions from transport have had little influence on these trends.

Improvements in the fuel efficiency of road freight should reduce the cost of road freight, which may in turn encourage increased demand for road freight (more tonne kilometres) - thereby offsetting some of the potential energy and carbon savings. This is termed the 'direct rebound effect'. Analogous effects occur in road passenger transport and have been extensively studied over the last 20 years. For example, a meta-analysis of the results from 76 studies of car transport found a mean long-run direct rebound effect of 32% - implying that one third of the potential energy savings from more fuel-efficient cars had been offset by increased driving (Dimitropoulos et al., 2016). But to date, only a handful of studies have investigated whether comparable rebound effects occur within the road freight sector.

This paper therefore seeks to contribute to the limited literature in this area by estimating the direct rebound effect for UK road freight over the period 1970–2014. The following section provides further background on this topic and summarises the empirical estimates that have been made to date. Section 3 describes our methodology, including the specification of the econometric models and the robustness tests used to select between them. Section 4 summarises our data sources and discusses the trends in the relevant variables. Section 5 presents our results, including the estimated rebound effects. The paper concludes by highlighting the limitations of our approach and the priorities for future research.

2. Background

Rebound effects in road transport are commonly investigated through econometric analyses of aggregate data on fuel use and travel patterns. This approach allows the rebound effect to be estimated from one or more elasticities, derived from the estimated parameters of the regression equation. The most obvious measure is the elasticity of demand for the relevant energy service (S) with respect to some measure of energy efficiency (ε): $\eta_\varepsilon(S)$. The elasticity of the demand for energy (E) with respect to energy efficiency ($\eta_\varepsilon(E)$) is then given by (Sorrell and Dimitropoulos, 2007):

$$\eta_\varepsilon(E) = \eta_\varepsilon(S) - 1 \tag{1}$$

Hence, if $\eta_\varepsilon(S) \geqslant 0$, a 1% improvement in energy efficiency leads to less than 1% reduction in energy consumption - or other words, some of the potential energy savings are 'taken back' by increased demand for the energy service. In the case of road freight, the energy service could be measured in either vehicle kilometres or tonne kilometres ('goods moved') – analogous to the choice between vehicle kilometres or passenger kilometres for car transport (Stapleton et al., 2016).

With the energy service defined as goods moved (tonne kilometres), the appropriate measure of energy efficiency ($\varepsilon = S/E$) is the fuel efficiency of goods moved (tonne kilometres per megajoule – tkm/MJ). Similarly, with the energy service defined as distance travelled (vehicle kilometres – vkm), the appropriate measure of energy efficiency is the fuel efficiency of distance travelled (vehicle kilometres per megajoule – vkm/MJ). In the empirical work below, we choose the first of these measures.

Independent estimates of fuel efficiency are frequently unavailable, or provide insufficient variation to give precise parameter estimates. Hence, an alternative approach is to estimate the rebound effect from one of three *price* elasticities, namely:

- the elasticity of goods moved with respect to the fuel cost of goods moved – $\eta_{p_S}(S)$;
- the elasticity of goods moved with respect to the price of fuel – $\eta_{p_E}(S)$; and
- the elasticity of fuel consumption with respect to the price of fuel – $\eta_{p_E}(E)$.

Where p_E is the price of fuel (£/MJ) and $p_S = p_E/\varepsilon$ is the fuel cost per kilometre (£/km). Under certain assumptions, the negative of each of these price elasticities can considered equivalent to the efficiency elasticity of goods moved (Sorrell and Dimitropoulos, 2007; Stapleton et al., 2016). But since the required assumptions are rather restrictive (especially for $\eta_{p_E}(E)$), there is a need for caution when comparing the results of studies that use different metrics for the rebound effect (Stapleton et al., 2016).

To illustrate the factors influencing fuel efficiency and freight transport, it is useful to decompose the fuel efficiency of goods moved (ε) as follows (Sorrell et al., 2008, 2009):

$$\varepsilon = \frac{TKM}{E} \equiv \frac{TKM}{VKM}\frac{VKM}{VKMT}\frac{VKMT}{E} \tag{2}$$

Or:

$$\varepsilon = lm\varepsilon_V \tag{3}$$

where E is HGV fuel consumption (megajoules - MJ), $VKMT$ is total distance travelled by HGVs (vehicle kilometres); VKM is distance travelled by loaded HGVs (vehicle kilometres); ε_V is the average fuel efficiency of distance travelled by (loaded and unloaded) HGVs (vehicle kilometre per MJ); m is the fractional amount of 'empty running' ($m \leqslant 1.0$); and l is the average payload weight of the vehicle fleet (tonnes). The fuel efficiency of goods moved therefore depends upon the fuel efficiency of distance travelled (ε_V), the amount of empty running (m) and the average load factor of vehicles (on a weight basis - l). These in turn depend upon the mix of different weight categories of vehicle within the fleet, the mix of commodities carried, the organisation of logistics, the amount of packaging