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Environmental policy, decision making, and rebound effects in the U.S. trucking sector

James J. Winebrake [a,*], Erin H. Green [b]

[a] Rochester Institute of Technology, One Lomb Memorial Dr., Rochester, NY 14623, United States
[b] Energy and Environmental Research Associates, LLC, 2 Babcock Farms Lane, Pittsford, NY 14534, United States

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ABSTRACT

New technologies and policies have improved the efficiency of heavy-duty vehicles operating in the United States. These improvements reduce transportation costs ($/mile) for firms and raise questions about firm-level responses to these lower costs. Of particular concern are potential *rebound effects* on energy consumption that would partially offset the benefits these new technologies and policies aim to achieve. Although recent quantitative research has suggested that rebound effects in the U.S. trucking sector are negligible, very little has been done to "ground-truth" these results through discussions with transportation firms in the trucking sector. Based on interview results with eight trucking firms, this paper discusses the key factors that influence firm-level decision making within energy efficiency policy regimes. In particular, we focus on elements of the rebound effect and the elasticity of travel activity with respect to fuel efficiency. We find that both direct and indirect rebound effects may be small for reasons discussed in the paper. These results help validate recent empirical studies that point to an inelastic relationship between transportation costs and vehicle miles traveled and help expand our understanding of rebound effects in the trucking sector, thereby providing important information for impact analysis and future policy development.

1. Introduction

Heavy-duty vehicles (HDVs), including large trucks and vocational vehicles such as buses, dump trucks and utility vehicles, consume a significant and increasing share of fuel in the US. For example, HDV Class 7–8[1] energy consumption was ~17.6% of total transportation energy use in 2013,[2] and is projected to reach almost 30% of transportation energy use by 2040 (U.S. Energy Information Administration, 2016; Oak Ridge National Laboratory, 2015). This increasing use of energy in the trucking sector has obvious impacts on emissions of greenhouse gases (GHG) and criteria pollutants, and the US government has been active in promoting technologies and policies that would promote more efficient vehicle operations (EPA & NHTSA, 2011). In particular, the U.S. Environmental Protection Agency (EPA) and the National Highway Transportation and Safety Administration (NHTSA) have promulgated regulations aimed at improving HDV fuel efficiency. EPA now regulates GHG emissions from trucks (e.g., with performance standards for gCO_2/ton-mile), and NHTSA regulates fuel consumption (in gallons/1000 ton-mile). These regulations are being implemented in stages, with Phase I standards affecting trucks produced between model years 2014 and 2018 (The White House, 2014a) and Phase II standards affecting trucks produced between model years 2019 and 2025 (The White House, 2014b).

The ability of these new standards to meet energy and GHG reduction goals is dependent not only on the stringency of the standards themselves, but also on the response to these standards by firms operating in the trucking sector. Researchers are now trying to understand how decision-making by trucking firms are influenced by these standards, which have the interesting impact of possibly *lowering* the operating costs of trucking firms. Of particular interest is the extent of the *rebound effect*, which has been studied extensively in the light-duty vehicle (LDV) sector, but is a nascent area of research for HDVs (De Borger & Mulalic, 2012; Matos & Silva, 2011; Winebrake et al., 2012; Berkhout, Muskens, & Velthuijsen, 2000; Greene, 2012; Greene, Kahn, & Gibson, 1999; Greening, Greene, & Difiglio, 2000; Small & Van Dender, 2005; Sorrell & Dimitropoulos, 2007; Winebrake et al., 2015a, b). A positive rebound effect suggests that as vehicles become more efficient and their operational costs per mile decrease, firms will increase fuel

* Corresponding author.
E-mail addresses: jjwgpt@rit.edu (J.J. Winebrake), greenerinh@gmail.com (E.H. Green).

[1] We use the US truck classification system in this paper, with Class 7 trucks having gross vehicle weight ratings between 26,001 and 33,000 lb; and Class 8 trucks having a gross vehicle weight rating over 33,000 lb.

[2] Note that this percentage increases when medium duty vehicles (Class 3–6 trucks) are included to 22.7%.

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consumption either directly (through additional travel or behavioral modifications) or indirectly (by passing along fuel savings to customers and inducing greater demand for HDV services) (Winebrake et al., 2012).

Empirical research to quantify the rebound effect for the HDV sector has shown mixed results, with some studies pointing to high rebound effects and others implying negligible effects in both the US (Winebrake et al., 2015a, b; Leard et al., 2015) and in other countries (De Borger & Mulalic, 2012; Matos & Silva, 2011; Wadud, 2016; Wang & Lu, 2014). The variety of results is due to several factors, including the geographical elements of each study; the heterogeneity of the sector; the application of different statistical models; the difficulty in separating direct and indirect effects; and the lack of detailed, disaggregated data on HDV travel behavior, to name a few.

This paper takes a qualitative approach to understanding the basis of the rebound effect in the US trucking sector by considering more generally firm decision making in light of changing policy and fuel price landscapes. In addition to presenting a review of the literature on this topic, we have conducted eight (8) in-depth interviews with trucking fleets to explore how they make decisions with respect to: (1) responses due to fuel price changes or energy efficiency improvements in their fleet; (2) the pass-through of fuel cost savings to customers or others (e.g., shareholders); (3) the management of vehicles; and (4) the management of driver behavior. We also explore their responses in the context of their key objectives (e.g., profit maximization; service quality; safety; etc.) and competitive advantage to better understand how incentives/disincentives might affect firm behavior, recognizing that market share is not based on costs alone. Note that for certain firms or services, there is no need for increased service by customers (i.e. waste management or other services).

Our goals are to use these interviews to gain greater understanding of decision making in the trucking sector to validate existing theory or quantitative findings, suggest new theoretical models for future empirical testing, or identify where additional research is needed. Although our focus is on the US trucking sector, we believe many of our results may also be applied in other international contexts.

The next section provides additional background information related to the rebound effect in the HDV sector, followed by a discussion of our methods and results. The final section places our results in the context of new policies and proposed research necessary to better understand and quantify the rebound effect in the trucking sector.

2. Background and literature review

2.1. Firm decision making in the U.S. trucking sector

Trucking is a complex component of any country's transportation sector, and this is especially true in the US, where companies of different sizes, types, and ownership characteristics help move goods from ports, to manufacturing facilities, to distribution centers, and ultimately to retail outlets and households. The trucking sector is energy intensive, especially compared to other modes of transportation such as rail and ship (Comer et al., 2010; Winebrake & Corbett, 2010; Winebrake et al., 2008), and the sector operates on tight margins where fuel costs can make up 30–40% of total operating costs (Torrey & Murray, 2014).

Adding to this complexity is the fact that trucking carriers are only part of a larger supply chain that includes shippers and receivers who are involved in contractual and market relationships defining not only the prices of transported goods, but also shipment sizes, levels of service, and other supply chain management conditions (Vadali et al., 2007). Thus, trucking firms are faced with making critical, real-time, multi-objective decisions in an environment that is constrained by suppliers, receivers, competitors, and even external conditions (e.g., traffic and weather). These decisions can have meaningful effects on fuel consumption (and therefore profit), and so they must be made carefully. Table 1, adapted from Demir et al. (2014), demonstrates the types of factors under the control of trucking firms that may affect fuel consumption in response to changing fuel costs.

Table 1
Factors that affect fuel consumption in the trucking sector, as adopted from (Demir, Bektaş, & Laporte, 2014) with additions by the authors shown in *italics*.

Category	Factors affecting fuel consumption
Vehicle related	Vehicle curb weight
	Vehicle shape
	Engine size/type
	Fuel type/composition
	Trailer aerodynamics
	Tire rolling resistance
	Hybrid propulsion
	Other (maintenance, age, accessories, etc.)
Traffic/travel related	Speed
	Acceleration/deceleration
Driver related	Driver aggressiveness
	Gear selection
	Idle time
Operations related	Fleet size and mix
	Payload
	Empty miles
	Vehicle miles traveled
	Number of stops

Overlaid on this already complex system is the role of regulation. In the US, new regulations affecting truck fuel efficiency will at the very least change the vehicle attributes mentioned above, especially through manufacturers' application of fuel saving technologies that range from light-weighting, to improved aerodynamics, to hybrid propulsion systems (Guerrero, 2014). These improvements have cost implications, both positive and negative. Vehicle modifications will typically come at a price, either as additional capital costs for vehicle add-ons or through higher initial costs as manufacturers pass along at least some of the costs of fuel saving technologies to trucking firms through higher vehicles prices. But these modifications also reduce fuel consumption at the firm level, lowering operating costs ($/mile) and saving the firms' money. The question we explore in this paper is how these cost implications affect firm decision making and whether those decisions have the potential to create rebound effects in the sector.

2.2. Understanding the rebound effect in the context of firm decision making

The "rebound effect" has received ever-increasing prominence in energy and environmental policy discussions over the past decade (Font Vivanco, Kemp, & van der Voet, 2016). In general, the rebound effect refers to an increase in energy demand resulting from improved energy efficiency. This increased demand could be due to (1) the decreased cost of the energy service, or (2) the increased consumption of other goods and services stemming from the reallocation of energy cost savings. There are various manifestations of the rebound effect in the context of vehicle efficiency examined in the literature (Winebrake et al., 2012; Sorrell, 2007, 2009). These emerge from the idea that vehicle efficiency improvements lower the costs of providing energy-related services (such as freight delivery). Three particular types of effects stand out for the trucking sector:

(1) The *direct rebound effect*, which we define as the increased consumption of energy services by carriers in the trucking sector due to vehicle efficiency improvements; for example, trucks traveling longer routes or at greater speeds because efficiency improvements have reduced their fuel costs per mile.
(2) The *indirect rebound effect*, which we define as the increased consumption of energy services in the trucking sector by customers (i.e., shippers and receivers) due to the pass-through of fuel cost savings from carriers to their customers in the form of lower freight rates due to energy efficiency improvements,

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