Research in Transportation Business & Management 12 (2014) 20–28

Contents lists available at ScienceDirect

Research in Transportation Business & Management

Co_2 emissions of French shippers: The roles of delivery frequency and weight, mode choice, and distance

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ARTICLE INFO

Article history:
Received 15 November 2013
Received in revised form 21 July 2014
Accepted 11 September 2014
Available online 26 September 2014

Keywords:
CO_2 emissions
Freight transport
Logistics

ABSTRACT

In this article, we describe the effects of delivery frequency, mode choice, distance, and shipment weight on the CO_2 emissions of French shippers, taking advantage of a 2004 survey of French shippers (ECHO) which describes the characteristics of 3000 shippers, 10,000 shipments, and 20,000 transport chain legs.
Once the energy consumption and CO_2 emissions of every shipment have been computed, they are divided by the corresponding number of ton-kilometres in order to find their carbon intensity (in grammes of CO_2 per ton-kilometre). We then analyse the latter with respect to a number of selected shipment characteristics: shipment frequency and mode choice (planning choices), and Euclidean distance and yearly tonnage shipped to the same customer (transport demand). We also develop two log-linear regression models in which carbon intensity is assumed to be caused by these characteristics. We find that shippers' transport planning choices have at least as much impact on carbon intensity as the characteristics of transport demand.

1. Introduction

The growth of freight transport and the resulting CO_2 emissions is a key challenge for a low-carbon future. The transport sector produces about a quarter of France's greenhouse gas (GHG) emissions and this proportion is continuing to increase. Freight transport also accounts for an increasing share of all transport, hence of all transport-related energy consumption and GHG emissions (MEDDTL — CCTN, 2006). There is currently no sign of it decelerating or decreasing. Reaching the political target of reducing GHG emissions related to human activity to a quarter of current levels calls for substantial structural changes. GHG mitigation actions include technological, behavioural and policy options: decoupling economic growth from freight traffic (EEA, 2008) and improving the carbon efficiency of freight, which includes modifying modal split (Woodburn & Witheing, 2010), improving the energy efficiency of vehicles and infrastructure, and increasing load factors. Whilst it is necessary to quantify CO_2 emissions to mitigate the consequences of transport activity the aim of this paper is in particular to provide an understanding of how the characteristics of logistics may affect emissions.

The paper is structured as follows. First, a review of the literature on CO_2 emission mitigation for freight is presented in Section 2. The data used in this paper is from a French shipper survey, the ECHO survey, which is presented in Section 3. The estimation of energy consumption is also discussed. Section 4 focuses on CO_2 emissions per shipment and explains how they are related to delivery frequency, mode choice, distance, and relations with customers (through annual exchanged volumes). Regression analysis complements this section. Conclusions are drawn in the final part, Section 5.

2. Literature review

Two streams of research have addressed the growth of freight transport and its resulting GHG emissions: 'transport energy and GHG emissions' on the one hand and 'green logistics' on the other. Transport and energy is a long-established research field, which began to study GHG emissions essentially in the 1990s. The growth of energy consumption in freight transport is perceived to be the outcome of economic growth (GDP in €), the transport intensity of the economy (tkm/€ of GDP), and average freight energy intensity (goe/tkm) which takes account of modal split and loading rate. Emission factors are applied to convert this energy into GHG. If a country's total energy consumption per mode is known, the quantitative problem therefore consists of balancing the equation that links energy use or CO2 emissions with parameters such as economic activity, freight transport demand and energy efficiency. Using such a decomposition of energy use for road freight, Kamakaté and Schipper (2009) compared the energy intensity of truck freight transport in five countries (Australia, France, Japan, the United Kingdom and the United States) from 1973 to 2005. This cross-country comparison highlights the influence of geography, transportation infrastructure and truck utilization patterns on energy and carbon intensity from this sector. They concluded that better

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http://dx.doi.org/10.1016/j.rtbm.2014.09.003
2210-5395/

planning/logistical policies, higher load factors, and better matching of truck capacity to loads could lead to major reductions in trucking energy use and emissions.

Piecyk and McKinnon (2010) also developed a framework that links economic performance to a series of logistical parameters and freight transport-related externalities. They define the relationship between the weight of goods and freight-related CO_2 emissions as a function of seven key variables which are influenced by a variety of related logistical decisions, product characteristics and external factors. Using a classification proposed by McKinnon and Woodburn (1996), they split the decisions into four groups. The key variables and the factors influencing them were explored during a series of seven focus group discussions with logistics experts. On the basis of these discussions, a two-round Delphi survey was used to canvass the opinions of a larger and more diverse sample of logistics and supply chain experts to measure the direction and strength of future developments likely to determine the environmental performance of supply chains.

The starting point of the second approach to freight CO_2 emissions was the development of logistics as an academic discipline. In his "brief history of Green logistics research", McKinnon (2010) suggested that the discipline came into being in the mid-1960s, primarily with the aim of reducing freight transport externalities. He discussed historical trends and priorities in connection with the development of this topic, from public sector interest in transport economics to private involvement in green logistics research, from local pollution in the 60s and 70s to the global atmospheric problem (the focus is currently returning to the local level as a result of the EU rules on particulate matter and NO_x concentration in urban areas).

Consolidating shipments has always been perceived as an effective way of increasing loading rates (Madre, André, Rizet, Leonardi, & Ottmann, 2010). Ballot and Fontane (2010) analysed not only how logistical network pooling can reduce the environmental footprint of logistics but also how much CO_2 emissions can be reduced if members of a supply chain collaborate to share their network resources. Using scenarios built with logistical data from companies, they estimated that pooling networks could bring about a potential reduction in CO_2 emissions of at least 25% (as compared to the current configuration).

To further quantify the impact of logistical choices on CO_2 emissions, Rogerson (2012) explored how the shipper's freight transport ordering process impacts the logistical variables as defined in the framework developed by Piecyk and McKinnon (2010): modal split, handling factor, average length of haul, lading factor, empty running, fuel efficiency and carbon intensity of fuel. The empirical evidence is based on an explorative multiple case study of routine freight transport ordering processes in manufacturing companies. Input was provided by shippers who described the transport ordering process and its links with internal processes. Information from shippers' interviews and literature was used to describe how the transport ordering process might influence logistical variables. The findings suggest that the timing of information input to the transport ordering process regarding transport requirements can influence lading factor and empty running by affecting opportunities for the transport provider to plan vehicle utilization. Rogerson (2012) also concludes that communication between the sales staff and the transport ordering staff about customer needs regarding delivery times can modify the urgency of transport and thereby influence modal split. In addition, information input to the transport ordering process regarding dimensions can affect planning of the space required for the shipment and the utilization of ordered space, thereby influencing lading factor.

To overcome the lack of appropriate data on energy efficiency, Leonardi and Baumgartner (2004) designed and performed an empirical survey on the energy efficiency of road freight transport. They collected data on fuel consumption and transport performance in 50 German haulage companies during 2003. Emissions efficiency ranged from 0.8 to 26 ton-km per kg of CO_2 emissions. The results show potential for improvements given the low vehicle usage and load factors, poorly selected vehicles and the high proportion of empty runs. This survey focused on transportation only, without linking it to shippers and their logistical organization.

Based upon this review, we propose that in-depth knowledge of the factors that influence firms in their planning/logistical choices as well as the factors that influence carbon efficiency would make freight GHG emission mitigation considerably easier. Our lack of knowledge is due to several factors, including the theoretical complexity of the problem, the insufficient resources that have been made available for freight compared with passenger transport, and the limitations of the existing data. The French shipper survey (ECHO[1]) developed in 2004 was an attempt to fill this gap.

In what follows, we describe the CO_2 emissions of French shippers using disaggregate data from the 2004 ECHO survey. We shall then narrow our approach so as to shed light on the effects on these emissions of delivery frequency, mode choice, distance, and relations with customers based on annual exchanged volumes. With this in view, we shall conduct exploratory data analysis and investigate two ad hoc linear regression models. The focus is on a detailed description of the effects of delivery frequency and mode choice on CO_2 emissions by building on a unique survey that contains very detailed statistical information about French shippers and the shipments they carry that originate in France. The limitation of this approach is in its theoretical contribution.

3. Data

The French Ministry of Transport provides an estimate of annual energy consumption and CO_2 emissions using the total amount of traffic for each type of fleet, and comparing the total consumption so estimated with the total amount of oil sold in the same year. However, this estimate covers both freight and passenger transport. We do not have a clear idea of the differences within the freight sector. The 2004 French shipper survey contains detailed information on the decomposition of freight flows that could be used to estimate the CO_2 emissions from French shippers.

3.1. The 2004 ECHO survey

The 2004 French shipper survey (ECHO) describes the characteristics of 3000 shippers, 10,000 shipments and 20,000 transport chain legs. Readers should note that the sample size for the research presented in this paper was 9316 shipments since some shipments were unexploitable as far as CO_2 emissions were concerned.

Design of the survey and sampling protocol are described in Guilbault and Gouvernal (2010) and Rizet and Keïta (2002). ECHO can be used to estimate energy consumption and CO_2 emissions (Rizet, Armoogum, & Marchal, 2004). It also allows us to analyse the extent to which some determinants of planning choices and freight demand are responsible for these.

This survey has two main features: a detailed description of shippers' characteristics, including organizational charts, and the physical tracking of a selection of shipments from departure to final delivery. The questionnaire covers three key dimensions:

1. *Shippers*: a few general questions were first asked about the overall volumes and structures of the in- and out-going transport flows, and the firm's own vehicle fleet. A face-to-face interview was then set up with the logistics manager. Questions were asked about the economic characteristics of the company: production, distribution and storage practices, relations with customers and suppliers, management & communication systems;
2. *Consignments:* once information had been collected about the shipper's industrial and logistical organization, a second part of the

[1] ECHO stands for *Enquête Chargeurs et Opérateurs* (Shipper and Operators Survey).