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Road and intermodal transport performance: the impact of operational costs and air pollution external costs

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ABSTRACT

The transportation of goods is essential for the economy, but it also contributes to air pollution which, in turn, affects human health. These negative impacts generate additional costs for society that are not necessarily taken into account in public transportation policies and in private transportation decisions of companies and individuals. This leads to inefficient transportation systems where the social equilibrium is not reached. Intermodal transport is promoted by the European Commission to reduce these negative externalities. The objective of this paper is to analyze at a strategic level the effect on modal split between road, intermodal rail and intermodal inland waterway transport of several economic or environmental policies. An intermodal allocation model is applied to the Belgian case in order to identify the modal split changes between the single minimization of costs (operational or health-related external) and the introduction of additional road taxes.

1. Introduction

Transportation activities have been increasing in the last years. Between 1995 and 2010, an annual transportation growth rate of 1.5% for freight (road, rail, inland waterway (IWW), oil pipelines, intra-EU air, intra-EU sea) and 1.3% for passengers has been observed in the European Union's 27 countries (European Commission, 2012).

Transportation of goods and people brings several advantages to society, both from the personal and the economic side. Freight transportation in particular allows access to previously unreachable goods, but also enables cost reduction for products developed in further regions at a lower price. Unfortunately, these benefits are also counterbalanced by undesirable features. Ricardo AEA (2014) states that "when side effects of a certain activity impose a cost upon society, economists speak of such a cost as an external cost." The negative effects generated by transport but not directly supported by the related sector are therefore known as transport external costs. The latter can be of various types such as climate change, air pollution, water pollution, congestion, accidents or noise.

Among these externalities, air pollution is receiving increasing interest. This is observable through several policy measures applied at different levels of decision. Some examples of these measures to mitigate air pollution are the development of European air pollutant standards, the introduction of low emissions zones or alternate traffic circulation in European city centers, the introduction in some countries of stronger speed limitations on highways when pollutant thresholds are reached, or the development and encouragement to use alternative transportation modes like rail or IWW (European Commission, 2011).

The World Health Organization (WHO) estimates that air pollution is now "the world's largest single environmental risk." In 2012, one out of eight people who passed away died because of air pollution exposure (WHO, 2014). Indeed, the emissions generated during the movement of goods directly affect air quality. A higher level of exposure to these chemical components increases the percentage of disease development and aggravation. Heart attacks, cancers and respiratory system illnesses are some of the negative impacts on human health generated by transport.

Human health external costs are divided into two categories: mortality and morbidity costs. Mortality costs reflect the reduction in life expectancy due to acute and chronic effects and are often computed through values of statistical lives (Ricardo AEA, 2014). The monetization of mortality costs is important since they represent the most important part of human health external costs (Ricardo AEA, 2014). Morbidity costs refer to the other costs generated by air pollution, such as costs of curing, costs of hospitalization, and costs of restricted activity days (Ricardo AEA, 2014). These consequences of transportation are not supported by transportation companies and impose a cost on society. For this reason, the limitation and reduction of transport air pollution are encouraged by the European Commission in its White Paper on Transport (European Commission, 2011).

Road is currently the most used mode for freight transport in Europe. Europe is willing to decrease its modal share and to go for more environmentally friendly modes in order to restrict the negative impacts

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of transport on its environment (European Commission, 2011). This objective can be achieved by the use of rail and IWW in the framework of an intermodal transport. Intermodal transport is defined as the transportation of goods using two or more modes of transport, in the same loading unit, without handling the goods themselves (United Nations, 2001).

Intermodal transport is generally composed of five main stages. Goods are first transported by truck for the pre-haulage from the origin node to the first intermodal terminal. At this first terminal, goods are transferred from truck to train or to barge. The long-haul transport by the more environmentally friendly mode is then performed on rail or IWW. At the second terminal, freight is transferred from train or barge to truck. The post-haulage, i.e. the last part of the travel, is done by truck until the final destination node. The main benefits of intermodal transport lie in the reduced costs and externalities of the environmentally friendly long-haul transport (Mostert & Limbourg, 2016).

Analyses of the relation between transport, air pollution, and human health are often performed at the urban level (de Leeuw, Moussiopoulos, Sahm, & Bartonova, 2001, Costabile & Allegrini, 2008, Bagienski, 2015, Lozhkina & Lozhkin, 2015, Tainio, 2015, Aggarwal & Jain, 2015). The focus is often, therefore, on a restricted mode and case study. However, a wider perspective of analysis at the strategic level is also needed to develop long-term transportation policies which account for human health impacts.

How do different modes of transport perform regarding human health external costs? Does the modal split between road and intermodal transport vary, when economic or human health objectives are followed? In an economic optimization strategy, can the intervention of states (for instance through the implementation of taxes) lead to the same modal split, as an environmental optimization strategy? Which modes of transport should be promoted in order to ensure reduced human health external costs? In which infrastructure projects should public authorities invest? What is the implication on modal split of external costs variations, resulting, for instance, from technological improvement or traction mix modifications?

This research aims to respond to these questions by filling the gap which exists in linking transport and human health external costs at a strategic level of decision making. This is done with tools of the operations research domain. For this purpose, an intermodal allocation model is used to compare the modal split between road, intermodal rail and intermodal IWW transport, under economic and environmental optimization strategies. An intermediate policy between economic and environmental optimization is also studied. This policy consists of public intervention through additional road taxes in a system which follows an economic optimization strategy.

The resulting flow distribution under operational costs or human health external costs minimization is analyzed. Sensitivity analysis of transportation external costs is also performed in order to evaluate how modifications of these costs influence the market shares of road and intermodal transport. The mathematical model is applied to the case of Belgium in order to practically emphasize which kinds of policy-related decisions can be provided.

The next section provides a literature review on the links between the modeling of freight transport and its impact on air pollution and human health, and a positioning of our research in this framework. Section 3 details the model formulation and elaborates on the used methodology. Section 4 concentrates on the used data for the case study. Section 5 focuses on the case study findings. Discussion of these results is provided in Section 6. Conclusions are drawn in the last part of the paper.

2. Freight transport, air pollution and human health impacts: What are the implications for business and stakeholders?

Transportation directly influences human health through the emission of chemical components which affect air quality. According to the Update of the Handbook on External Costs of Transport (Ricardo AEA, 2014), the most important emissions related to transport are sulfur dioxide (SO_2), nitrogen oxides (NO_x), Non-Methane Volatile Organic Compounds (NMVOCs) and particulate matters (PM). Particulate matters are divided into two categories: PM2.5 and PM10, representing the particles of a diameter size <2.5 and 10 μm, respectively.

These gases emitted by transport are responsible for several harmful impacts such as asthma, inflammation of the respiratory system, headaches, anxiety, cardiovascular diseases, effects on the central nervous system, lung diseases, cancers and premature mortality (EEA, 2013a). The combination of some of these emissions also contributes to the generation of ground-level ozone (O_3), leading to breathing difficulties, especially for young, old or sensitive (for instance, asthmatic) people.

Since these emissions are generated by the transportation companies, but impose a cost on other economic actors of society, they are recognized as externalities or external costs. The non-consideration of externalities on the economic market leads to the production of a higher quantity of transport services than the optimal societal one. As transport externalities can be considered to be market failures, they might provide a rationale for government intervention (for instance through the introduction of additional taxes) in order to reach the societal optimal level of transport.

Several stakeholders like shippers, public authorities, private individuals and private companies may benefit from introducing external costs in transportation planning policies.

Shippers may take advantage of an improvement in their transportation mode attractiveness. This can increase the market share revenues of owners of more environmentally friendly modes.

Government and public authorities mainly support the costs of public health care and hospitals. By ensuring a restricted amount of transport externalities, public authorities could reduce the budget assigned to these services. In Europe, between 46% and 66% of total healthcare expenses were used for curative and rehabilitative care in the different states in 2012 (European Commission, 2015c). Limiting health-related externalities may thus help states better control healthcare expenditures. This is still a major problem in all types of healthcare systems (Wendt, 2009). Some public deficits may thus be recovered, or some money could be transferred to other areas of expenses. These savings are welcome in times of economic crisis when the European Union encourages the reduction of public debt of the member states (European Commission, 2016).

Private individuals also benefit from transport externalities being taken into account in transportation policies. The potential advantages happen at two levels. First, by explicitly making decisions related to the restriction of these external effects, people may enjoy a healthier way of life. Second, households need to invest less money in healthcare expenses, which alleviates their global budget.

Finally, private companies may also benefit from reduced externalities through transportation policies. Indeed, air pollution is responsible for the development of serious health problems such as cancers or heart attacks. The latter often imply sickness absences for employees who do not work anymore. This has a cost for companies which pay sick leave to their members (Gimeno et al., 2014). In addition, new employees might need to be hired and trained to replace the sick person, which also represents an indirect cost to support. Consequently, even if the effects of air pollution related to transport are not directly noticeable, their impact on society is not marginal and concerns a lot of economic actors.

The enhancement of human health preservation is currently done through the setting of global reduction targets for air pollutant emissions. At the world level, air pollution matters are consolidated in the United Nation Economic Commission for Europe (UNECE) Convention on Long-range Transboundary Air Pollution (LRTAP). Introduced in 1979, this convention is the first international legally binding tool developed to limit air pollution. It has been followed by a set of protocols aiming at enforcing the transboundary air pollution abatement (UNECE, 2015). At the European level, the National Emission Ceilings

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