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Economic valuation of Well-To-Wheel CO_2 emissions from freight transport along the main transalpine corridors

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ABSTRACT

CO_2 emissions are one of the main externalities related to freight transport. Their evaluation is extremely difficult, due to the presence of several scientific and economic uncertainties. This paper discusses the approaches currently adopted by literature to deal with CO_2, proposing a methodology based on a Well-To-Wheel quantification and an economic valuation deriving from a meta-regression. A freight transport analysis is then provided for one of the most critical areas of Europe, the Alps. Here, the different approaches adopted by the single nations determine divergent results in terms of modal shift towards rail and, consequently, CO_2 emissions. An integrated and transnational strategy could lead to better results, avoiding detoured traffic and increasing the share of railway traffic. To this aim, the carbon impacts of three specific alpine-wide measures are evaluated: namely, Alpine Crossing Exchange, Emissions Trading and Differentiated Toll System. In comparison with business-as-usual scenario, the case study reveals a potential CO_2 saving up to more than 600,000 tons and 38 M€ for the year 2030, thus providing policy makers with an integrative transnational tool able to evaluate the long-term carbon impact of their transport decisions.

Introduction

One of the main elements to determine transport sustainability is the evaluation of the greenhouse gas (GHG) emissions (Sinha and Labi, 2007; Black, 2010): at European level, transport counts for 24.3% of total emissions (EU, 2014), which makes it the second most polluting sector after energy production. Policy makers are aware of this critical condition. Since the early 1990s, EU has constantly increased its efforts to reduce GHG emissions (EC, 2014a) and many sectors (e.g., agriculture, industry, buildings) have obtained encouraging results. However, this is not valid for transport, where GHGs have increased by about 22% in comparison to the 1990 levels (EU, 2014) and particularly for road freight transport, where emissions have increased by more than 35% (Enerdata, 2015).

In freight transport operations, carbon dioxide (CO_2) is the main component of GHGs and counts 93–95% of total emissions. CO_2 emissions are thus a valid indicator to assess the global warming caused by freights (McKinnon and Piecyk, 2011). Among the possible approaches to limit CO_2 emissions, the reduction of unitary values is considered relevant (EC, 2014b). Currently, a shared European methodology to calculate carbon pollution from freight transport does not exist. CO_2 emissions of light commercial vehicles are already monitored (EU regulation 510/2011), but comparable standards are not available for Heavy Duty Vehicles (HDVs). According to McKinnon (2005), this is due to several factors, such as the capacity and the load

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factors of the vehicles, the adoption of parameters derived from international studies, the unity of measure (volume, weight or number of vehicles). To address this issue, EU is supporting the development of a simulation tool called the Vehicle Energy Consumption Calculation Tool (VECTO; Fontaras et al., 2013), which is expected to provide the first results in 2017. The technological development of vehicles is not enough to curb CO_2 emissions: specific measures and policies to encourage a modal shift towards less polluting transport systems are necessary as well (Dray et al., 2012).

This paper focusses on the assessment of several alternatives to reduce CO_2 from freight transport in one of the most delicate areas of Europe, i.e. the Alpine arch. Here, emissions can be up to five times higher than in the plains due to the morphology and the presence of slopes (Alpnap, 2007). Hence, particular attention is required in planning adequate freight transport measures to reduce CO_2 emissions. The Alpine arch is treated as a unique space in several transport studies (Reggiani et al., 2000; Dalla Palma et al., 2001; RappTrans AG and ProgTrans AG, 2004; Neuenschwander et al., 2011; Dörnenburg et al., 2015; Lückge et al., 2015), mostly focussing on the amount of freight and passengers monitored in the past and expected for the future. Only a few studies consider CO_2 impacts: Ryan et al. (2005) assess HDV CO_2 emissions and propose a scenario for the year 2025. iMonitraf! (2012) develops four scenarios for the year 2020 along the main five transalpine corridors. However, none of them provides an economic valuation of specific transport measures.

To address this issue, this paper proposes a two-step process. First, Section 'Methods to quantify CO_2 transport emissions' reviews the methods currently available to quantify CO_2 emissions from freight transport, suggesting the adoption of a Well-To-Wheel approach that considers the entire energy process from fuel production to consumption. Second, an economic valuation is performed through a meta-regression analysis. Sections 'Freight alpine transport' and 'Evaluation of future WTW CO_2 emissions' test this method to valuate the economic impact of CO_2 emissions for the adoption of specific measures for freight transport along the main transalpine corridors. The paper concludes with some policy considerations that also highlight the role of a correct evaluation of GHG emissions deriving from freight transport.

Methods to quantify CO_2 transport emissions

The methods adopted to quantify the impact of transport CO_2 emissions are rather heterogeneous, including different phases of the fuel production and emission.

The most thorough method to analyse the complete process is the Life-Cycle-Assessment (**LCA**; A3PS, 2015). It covers the entire life cycle of a product, process or activity, encompassing the extracting and processing of raw materials; manufacturing, transportation and distribution; use, re-use, maintenance; recycling and final disposal. The application of traditional LCA methodologies are mostly product oriented: the aim of such analysis is to describe the processes necessary to obtain industrial and manufactured products (Cass and Mukherjee, 2011). Local specifications are normally not considered. Emphasis is on using estimated inventories and the assumption of uniform conditions. However, CO_2 emissions cannot be included in such analysis because they are highly dependent on the context and the specific energy sources adopted.

With the Well-To-Wheel approach (**WTW**; Edwards et al., 2014), the impact of a fuel can be determined through the description of specific pathways. These pathways are complete sets of assumptions about the resource used, including the primary energy source, the energy required for its extraction, transformations, transportation, fuel production and characteristics of the vehicle using the fuel. To guarantee a clear distinction between the emissions related to the primary energy source and those linked to the propelling technology, WTW is subdivided to the Well-To-Tank (WTT) and the Tank-To-Wheel (TTW) approaches.

WTT describes the pathway necessary for the process of distributing fuels suitable for transport powertrains. Five main phases characterise this approach: production and conditioning of the energy, its transformation at source, transportation to market, transformation near the market and conditioning, and distribution of the finished fuels to the individual refuelling points (Edwards et al., 2013a). The energy required for fuel production can be expressed in terms of gCO_2/MJ (or $gCO_2/kW\,h$). For petrol, unitary emissions are calculated at about 13.05 gCO_2/MJ (Edwards et al., 2013b). By adopting the adequate conversion factors, the results of the WTT analysis for petrol and diesel (Table 1a) determine a unitary emission of 532.59 and 447.43 gCO_2/l respectively. According to the efficiency of the vehicle, it is possible to transform such a value in terms of gCO_2/km. For example, the average consumption of an HDV engine equals to 2.8 km/l, which determines a unitary WTT emission equal to 190 g/km, while the efficiency of an economy car (17 km/l) reduces WTT unitary emissions to 26.32 g/km.

For railway transport, the process is more complex because the energy mix required to produce the electricity is the sum of different primary resources. For each of them, the provision (extraction and transport) of raw materials as well as the efficiency of energy production and distribution have to be included in the evaluation. The WTT electricity efficiency can be defined by multiplying the specific energy consumption required to transport 1 t of freight (function of the technology) by the CO_2 emissions deriving from the production of the necessary electricity. In Table 1b, an example of a freight train of 1200 t is provided, according to the energy production of four different Alpine countries: Austria, France, Italy and Switzerland. In this last country, most of the electricity is produced by adopting renewable sources and thus the final value is significantly lower than for other countries like Italy, where most of the energy is produced by adopting coal power plants.

TTW quantifies the unitary energy expended and the polluting substances emitted by a vehicle during its driving cycle. It includes evaporative and tailpipe emissions during the operation of the vehicle and it is obtained through specific emission models. The final values are determined by several factors, which can be classified into six main groups: travel, facility, driver, vehicle, fuel, environment (Table 2).