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Freight futures: The potential impact of road freight on climate policy ☆

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ABSTRACT

This paper describes changes to the modelling of the transport sector in the WITCH (World Induced Technical Change Hybrid) model to incorporate road freight and account for the intensity of freight with respect to GDP. Modelling freight demand based on the intensity of freight with respect to GDP allows for a focus on the importance of road freight with respect to the cost-effective achievement of climate policy targets. These climate policy targets are explored using different GDP pathways between 2005 and 2100, which are sourced from the Shared Socioeconomic Pathways (SSPs) database. Our modelling shows that the decarbonisation of the freight sector tends to occur in the second part of the century and that the sector decarbonises by a lower extent than the rest of the economy. Decarbonising road freight on a global scale remains a challenge even when notable progress in biofuels and electric vehicles has been accounted for.

1. Introduction

The demand for freight transport has been evolving based on the transformation of economies across the globe. Within the most recent IPCC WG3 report (Section 8.9.1) it was noted that while integrated assessment models project that freight transport emissions will increase at a slower pace than passenger transport, notable emission increases will still occur. Based on the IAMC (Integrated Assessment Models Community) scenario database, the IPCC report notes that total freight transport emissions will "rise by as much as threefold by 2050 in comparison to 2010 levels [and that] freight demand has historically been closely related to GDP" (Sims et al., 2014). Reviewing the future of freight is important as it is a sector that will be difficult to decarbonise before the middle of the century and in a range of IAMs the sector remains dependent upon liquid fuels that can only be partially decarbonised through the use of biofuels (Capros et al., 2012; Pietzcker et al., 2014). Indeed, Chapman (2007) noted that while technological break-through in fuels, fuel efficiency improvements and routing/scheduling will impact emissions and be important, the major challenge for freight is that demand continues to grow. He also noted that improved logistics and efficient vehicle loading are the most viable solutions until technological advances, dematerialisation and modal shift can have a significant impact on emissions. With respect to the challenge of decarbonising freight, Eom et al.

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(2012) noted that the growth in freight transport emissions tended to outpace passenger transport emissions in most of the eleven IEA countries they focused upon in the period between 2007 and 2010. In addition, they found that there was little evidence of a shift away from road freight and that growth in trucking was higher than that seen in rail and water freight for most of the IEA countries reviewed.

In order to investigate the importance of freight with respect to different demand and climate policies, this paper develops projections of freight demand which are evaluated based on the intensity of road freight with respect to GDP for 62 countries between 1990 and 2010. The freight intensity of GDP is then applied to three sets of GDP pathways between 2005 and 2100, which are sourced from the Shared Socioeconomic Pathways (SSPs) database, and three carbon policy scenarios. A matrix of nine scenarios is defined in order to explore the different road freight futures under different economic and climate mitigation settings. Implementing these scenarios in the WITCH (World Induced Technical Change Hybrid) model allows for an analysis of the challenge that decarbonising road freight with technological advances presents when modal shift and reduced freight demand are not viable options. The WITCH model has been chosen as the basis of the analysis as it is an integrated assessment model with a detailed representation of road transport that includes demand intensity based on GDP, vehicle composition of the fleet and technological advances in biofuel and battery technologies. Chapman (2007) identified five alternate fuels and vehicles that are likely to be related to decarbonisation of road transport. Amongst these five vehicle options, the WITCH model contains endogenous and flexible modelling of advances in biofuels, hybrid electric vehicles and battery powered vehicles, but does not model gaseous fuels and fuel cell vehicles as decarbonisation options.

Within Bosetti and Longden (2013), this model was adapted to analyse the passenger road transport sector, focusing in particular on Light Duty Vehicles (LDVs) and specifically assessing the importance of Electric Drive Vehicles (EDVs) in achieving cost-effective climate policy targets. This paper will utilise a revised version of the same model that has been expanded to include a road freight module and perform a similar analysis as the previous paper with a focus on the importance of freight. In doing so, the paper will aim at highlighting how important the decarbonisation of the freight sector may be in the future given different GDP pathways and mitigation targets. With total demand exogenously fixed, the crucial factor will then be the amount of decarbonisation that can occur at least cost within the road freight sector, as opposed to other sectors.

Section 2 provides a description of the modelling of road freight within WITCH, as well as clarifying the range of decarbonisation options available within the model and describing the main calibration data utilised in the model. Section 3 focuses on freight demand and the freight intensity seen in historical data. Section 4 provides detail on the GDP and climate policy scenarios that are utilised in the subsequent section. Section 5 shows and discusses the results of the analysis in terms of the number of freight vehicles necessary to meet the differing levels of freight demand, the fleet composition, the fuel mix and the contribution of the sector in decarbonising the economy under the explored scenarios. Section 6 concludes this paper with an overview of the findings discussed in the paper.

2. Modelling road freight in WITCH

WITCH is an integrated assessment model that aims at developing optimal scenarios to study the energy, economic and environmental dimensions of climate change in the 21st century, starting from 2005. It is defined as a hybrid model because it combines characteristics of top-down and bottom-up modelling: the top-down part consists of an inter-temporal optimal growth Ramsey-type model that is combined with a detailed and disaggregated description of the energy sector, which is the bottom-up part of the model. The model is structured using a Constant Elasticity of Substitution (CES) framework, schematised in Fig. 1.

The aggregated nodes of capital (K) and labour (L) are combined with each other and this is then combined with the overall energy services node (ES) to produce the economic output of the model. Energy is divided into the capital of energy R&D (RDEN) and the actual energy generation (EN). Energy generation is computed using a nested production function resulting from the aggregation of different technologies with different elasticities of substitution. The first distinction is between the electric (EL) and non-electric sector (NEL), with a progressive disaggregation down to the single technologies. A thorough description of the CES structure is reported in Carrara and Marangoni (2016).

The transport sector is defined in two distinct sections of the model. The whole transport sector with the exception of road passenger (LDVs only) and road freight is captured in the aggregated non-electric tree. LDVs and road freight, instead, are explicitly modelled in a way which will be described shortly and do not directly appear in this CES structure.

The model is defined on a global scale: world countries are grouped into thirteen regions, defined on the basis of geographical or economic coherence. The regions behave independently but do interact with each other through a non-cooperative Nash game. The thirteen economic regions are USA (United States), WEURO (Western EU and EFTA countries), EEURO (Eastern EU countries), KOSAU (South Korea, South Africa and Australia), CAJAZ (Canada, Japan and New Zealand), TE (Transition Economies, namely Russia and Former Soviet Union states and non-EU Eastern European countries), MENA (Middle East and North Africa), SSA (Sub-Saharan Africa except South Africa), SASIA (South Asian countries except India), EASIA (South-East Asian countries), CHINA (People's Democratic Republic of China and Taiwan), LACA (Latin America and Central America) and INDIA (India). Technological change in energy efficiency and specific clean technologies is endogenously modelled, reacting to price and policy signals. All economic quantities are expressed in 2005 US dollars. A more detailed description of the model can be found in Emmerling et al. (2016) and on the model websites: www.witchmodel.org and http://doc.witchmodel.org/.