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Transport infrastructure costs in low-carbon pathways

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ABSTRACT

The rate and manner in which transport infrastructure (e.g. roads, railway tracks, airports) is deployed, will play an important role in determining energy demand, greenhouse gas emissions and the economic impact of the transport sector. This paper describes an exercise where the costs of infrastructure deployment for the transport sector have been incorporated into the IMACLIM-R Global E3 IAM. In addition to adding these costs, the modelling of the criteria for the deployment of infrastructure for roads has also been improved. It is found that this model recalibration results in a more accurate baseline as compared to historically observed data (2001–2013) for investments in energy demand, road infrastructure, and passenger kilometers travelled. Regarding macroeconomic effects, it is found that the imposition of a carbon emission trajectory to 2100 cause GDP to decrease relative to the newly calibrated baseline – this is a standard IAM result. However, when the deployment of infrastructure for roads and air travel is further constrained, the GDP loss is less than with a fixed carbon emission trajectory only. This is because early restriction of infrastructure for roads and air travel allows an expansion of public transport infrastructure which is adequate to meet low-carbon transport service demand whereas when less public transport infrastructure is available, more costly mitigation investments must be made in other parts of the economy. This suggests that restricting infrastructure deployment as a complementary policy to carbon pricing, lowers the cost of mitigation.

1. Introduction

Global greenhouse gas (GHG) emissions from the transport sector have more than doubled since 1971, increasing at a faster rate than those from any other energy end uses sector to reach 7.0 $GtCO_2$ in 2010. Over three quarters of this increase has come from road vehicles. Direct emissions from the transport sector were about 13.5% of total anthropogenic GHG emissions in 2010 or 22% of total global energy related CO_2 emissions (Sims et al., 2014). Greenhouse gas mitigation scenarios that keep to 2 °C of global warming suggest the need to reduce global emissions to net zero in the second half of this century (Edenhofer et al., 2014). Thus significant reductions in emissions from the transport sector will be necessary as part of any mitigation strategy (Clarke et al., 2014).

Reducing transport emissions is however a daunting task given the ever increasing demand, the slow turnover of stock and infrastructure[1] and the huge sunk costs in the present transport system (Sims et al., 2014). The authors emphasise the

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[1] The word infrastructure is itself relatively new in linguistic usage and it did not appear as a subject of interest in economics until the 1980s (Prud'homme, 2005).

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importance of both the actual transport technology e.g. vehicles and the enabling infrastructure, e.g. roads. Davis et al. (2010) calculate the emissions that will accrue from the use of the existing stock of vehicles (116 $GtCO_2$) and write that the average lifetime for a vehicle in the US is 17 years. Guivarch and Hallegatte (2011) on the other hand highlight the role of transport infrastructure, writing that transport infrastructure and asset locations create an inertia on transport emissions, which is larger than the inertia of the vehicles fleet itself. In other words the type of transport infrastructure in place can lock-in the sector to a particular pattern of emissions[2] that will be greater than the emissions from the vehicles calculated by Davis et al. (2010). In their study Guivarch and Hallegatte (2011) extend the work of Davis et al. (2010) to account for the neglection of the role of transport infrastructure in determining future levels of emissions. Focusing on physical infrastructure for transport and buildings Müller et al. (2013) show that if the per-capita levels of infrastructure enjoyed by people in Western countries was constructed globally using current technologies that this would use up about 35–60% of the remaining carbon budget available until 2050 if the average temperature increase is to be limited to 2 °C. In other words the emissions from the construction of infrastructure are important as well. Globally, at least 25 million kilometers of new roads are anticipated by 2050; a 60% increase in the total length of roads over that in 2010 (Laurance et al., 2014). Thus estimations of future emissions from the transport sector should consider not only, the stock of vehicles but in addition the 'induced demand' from the infrastructure and the emissions from the construction of the infrastructure itself.

Waisman et al. (2013) go further than the aforementioned authors by advocating for the consideration of behavioral determinants of transportation, which they write include (1) spatial organization at the urban level, (2) the level of investments in public transport and (3) the logistics organization which determine the transport intensity of production/distribution processes. The authors find that combining transport policies (e.g. dedicated investment in infrastructures for public modes) and a carbon price, can noticeably reduce the level of carbon tax necessary to reach a given climate target relative to a 'carbon price only' policy. This is because the policies explored lead to mode switching from individual to mass transport and this in itself reduces greenhouse gas emissions thus necessitating a lower carbon price to achieve a given level of emission reductions. Waisman et al. (2013) write that to date that E3 IAM modelling of global energy demand had not taken such issues into consideration. This is important because Integrated Assessment Models (IAMs) have become central tools for informing long-term global and regional climate mitigation strategies (EU, 2013), and have evolved to typically incorporate all aggregated sectors of energy end use e.g. transport, industry, buildings and in some cases agriculture and land use change. For energy supply however the lack of inclusion of infrastructure can mean that solar power and natural gas are assumed to develop regardless of the existence or not of power lines. For the transport sector this could mean that demand for transport services is modelled to evolve regardless of the existence or not of a road and rail infrastructure.

In addressing greenhouse gas emissions from the energy system, sector focused modelling works and policy discussion documents have traditionally focused on end-uses of energy e.g. heating, lighting, driving and not so much on the enabling physical infrastructure. Notable exceptions to this are Dulac (2013) and Laird et al. (2005). Dulac (2013) uses results from the IEA Mobility Model (MoMo) to model the infrastructure requirements to support projected road and rail travel through 2050, as identified in the IEA Energy Technology Perspectives 2012 (IEA, 2012). The author finds that net savings in expenditure on infrastructure of USD 50 trillion can be made in an 'avoid-shift' scenario where there is increased use of more sustainable modes of transport. Laird et al. (2005) take a macroeconomic perspective and argue for the inclusion of transport infrastructure in modelling works because its deployment and network effects bring about accessibility, which stimulates development i.e. wages, prices outputs, labour and land markets and can help remove market imperfections.

A stocktaking exercise (Ó Broin and Guivarch, 2015) carried out for the ADVANCE project[3] to assess the level of infrastructure representation in IAMs, revealed that infrastructure modelling to date in IAMs was rudimentary and mostly involves linearly related cost increments for deployed technologies. The exercise showed that five models, REMIND, IMACLIM-R, IMAGE, MESSAGE and TIAM-UCL, include energy transmission and distribution infrastructure e.g. natural gas grid or CCS pipelines as individual technologies. The IMAGE model (van Ruijven et al., 2011) and REMIND (Pietzcker et al., 2014) also incorporate some network effects. These are that in IMAGE large scale hydrogen use is restricted until the supporting infrastructure has been modelled to exist while in REMIND the quadratic scale-up of an overlay grid is required for the scale-up of VRE (Variable Renewable Energy). Waisman et al. (2013) as mentioned above, describe the incorporation of transport infrastructure into the IMACLIM-R Global E3 integrated assessment model, in order to analyze its role in facilitating modal shift or behavioral change towards more sustainable modes of transport. Their model includes road, public transport and air travel infrastructure. It was found that the other models only include the energy supply system for transport e.g. a hydrogen supply infrastructure.

This paper offers a further contribution using the same model as Waisman et al. (2013). Its development on the work of Waisman et al. (2013) is to, (i) incorporate the costs of construction and maintenance of transport infrastructure into an IAM, and (ii) develop a more sophisticated approach to how the infrastructure capacity for automobiles evolves. Note that recharging or refueling infrastructure for alternative fuel vehicles (Electric Vehicles (EV), Fuel cell, etc.) are not included in the analysis. Although the importance of recharging or refueling infrastructure deployment has been identified as one important factor for the transition to alternative fuel vehicles (Greene et al., 2014; Lin and Greene, 2011) the overall investment cost for such infrastructure is a lot less than the investment for transport infrastructure (roads, railways, etc.) themselves. This analysis therefore focuses on the latter. It is thus assumed in this work that growing demand for AFV's does

[2] For example the construction of the interstate highway in the United States allowed for greater commuting distances and thus the suburban housing developments and the car-dependency that went with this (Lecocq and Shalizi, 2014).

[3] EU FP7-ADVANCE Project: http://www.fp7-advance.eu/.