[*WHAT DRIVES CO_2 EMISSIONS FROM THE TRANSPORT SECTOR? A LINKAGE ANALYSIS*]

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Overview

The transportation sector contributes to a large share of the CO_2 emissions in China. However, with the exception of direct carbon emissions caused by energy consumption, the transportation sector also requires inputs produced by other sectors to satisfy its final demand and thus induces indirect carbon emissions which also cannot be ignored. But most of those previous literature only payed attention direction CO_2 emissions induced by direct energy consumption in transportation sector and neglected the indirect CO_2 emissions from the intermediate purchases and sales between transportation sector and the rest of the economy. Thus it is necessary to take consideration on sectoral linkages of transportation to identify its real influence on the carbon emissions of the whole economy.

Methods

Using data from input-output tables for 2002, 2007, and 2012, we applied the hypothetical extraction method (HEM) to reveal the characteristics of the backward and forward CO_2 emissions linkages between each transportation modal sub-sector (i.e. the rail, road, water, and air sub-sectors) and other economic sectors. HEM is a method used to analyze sectoral linkages by first of all extracting hypothetically a sector from the economy. That is, the extracted sector cannot sell products to other sectors and also cannot purchase products from these other sectors. The sectoral linkages are then quantified by computing the output loss of the rest of the economy after the extraction. The principle behind the hypothetical extraction method (HEM) for measuring CO_2 emissions linkages is to compare the CO_2 emissions of the whole economy with that of a hypothetical economy in which one or more target sectors are extracted. According to the method described by Duarte et al. (2002), the CO_2 emissions related to the target sectors can be decomposed into four separate components, namely, internal emissions (*IE*), mixed emissions (*ME*), net backward linkage emissions (*NBLE*), and net forward linkage emissions (*NFLE*). Here *IE* is the CO_2 emissions related to the block Qs itself. The CO_2 emissions come from the intermediate goods produced, sold and purchased inside the block *Qs*. ME is the CO_2 emissions in block *Qs* which are generated by the goods that sold from *Qs* to *Q-s* to form part of goods in *Q-s* and then repurchased by *Qs* from *Q-s* as intermediate inputs of *Qs*. *NBLE* is the net CO_2 emissions released from goods imported from *Q-s* to satisfy the final demand of Qs, while *NFLE* is the net CO_2 emissions released from goods exported from *Qs* to *Q-s* to satisfy the final demand of *Q-s*. In this study, *Qs* represents the transportation while *Q-s* represents other sectors in the economy.In order to analyze the resulting CO_2 emissions linkages from the perspective of both total production and consumption, we define output emissions (*OE*) and demand emissions (*DE*) as follows: $OE=IE+ME+NFE$ and $DE=IE+ME+NBE$.

Results

First, from the input-output relationship of transportation sector we know that the indirect CO_2 emissions intensities all exceeded the direct CO_2 emissions intensities in different transportation modal sub-sectors, representing more than 60 % of total (direct + indirect) emissions intensities as shown in Fig. 1. For the whole transportation sector, its real carbon impact on the whole economy during intermediate trade is far more than its direct carbon emissions from energy consumption. Meanwhile, the transportation sector has a large push effect on the economy's carbon emissions by providing transport service to other sectors.

Third, between 2002-2012, the OE and DE of road sector all increased and in 2012 they were far more than other transport sub-sectors, which indicates road sector is principal CO_2 emitter in the transportation sector. While for water sector, the OE and DE all decreased between 2007 and 2012 due in large part to the 2008 global financial crisis, which significantly affected international shipping. For rail sector, the OE and DE in 2007 and 2012 all decreased compared with those in 2002, which likely a result of technological development and energy structure adjustment. The development of high-speed rail These technological changes led to energy structure changes, from

coal-fired dominated to diesel-fired dominated and then electricity dominated energy feedstocks. Futhermore, the NFLE and NBLE has the largest share in OE and DE resperctively. It show that the transportation sector has a close relationship with other sectors in the economy, and for the CO_2 emissions reduction of the whole economy these sectoral CO_2 emissions linkages should be considered when considering policy options.

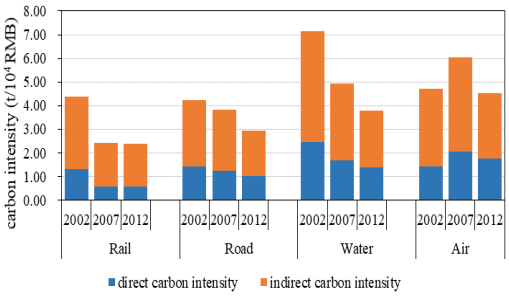

Fig. 1. CO2 emissions intensity of the four transportation sub-sectors in three different

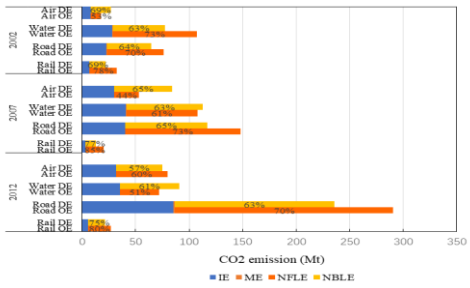

Fig. 2. Decomposition of CO2 emissions linkages to transportation in 2002, 2007 and 2012

Finally, according to the net transfer emissions (*NTE*) of each transportation sub-sector, rail and road transportation are CO_2 emissions exporters. During 2002-2012 the water transport sub-sector changed from a CO_2 emissions exporter to importer. Its final demand is the main factor that influences its CO_2 emissions. In contrast, the air transport sub-sector changed from a CO_2 emissions importer to exporter, with an increase in the use of energy industry resources. As a high-carbon sector, the transportation sector mainly transfers CO_2 emissions to downstream sectors such as service and construction industries through the supply chain of the whole economy, meanwhile transportation sector imported large CO_2 emissions from energy producing industry.

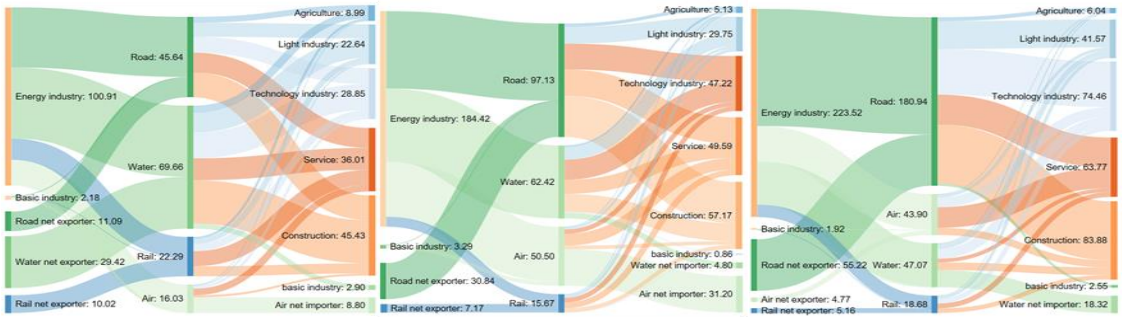

Fig. 3. Decomposition of net transfer of each transportation sub-sector (Mt)

Conclusions

Policy implications of how to reduce carbon emissions of the whole economy from the perspective of transportation sector can be derived from the above results as following. As carbon exporters, road, rail, and air transport sectors discharge CO_2 emissions to the economy, that is their net forward linkage emissions are higher than their net backward linkage emissions. Therefore, to reduce energy consumption and carbon intensity of these sectors is of paramount importance to achieve carbon reduction of the whole economy.

Different from the above three transport sectors, water transport sector is a carbon importer. To satisfy the final demand from water transport sector, the indirect CO_2 emission produced in the production process of its intermediate inputs should be attracted more attention. Improving input-output efficiency and reducing the dependence on carbon-intensive intermediate input are useful measures for water transport sector to control embodied CO_2 emissions. It is worth noting that the water transport sector imported large CO_2 emissions form energy industry particularly oil processing industry. Hence, solving the energy problem is also important in water transport sector.

In summary, improving energy efficiency and developing alternative fuels are effective ways to promote low carbon development in transportation sector. These measures mitigate not only the direct carbon emissions produced by energy consumption of transportation sector, but also the indirect carbon emissions produced in the other sector (e.g. energy producing sectors). To achieve carbon reduction of the whole economy, it is more important to pay attention to the CO_2 emissions linkages and to be more cautious about carbon leakage between industrial sectors. For example, the rail sector could use more clean electricity in high-speed railway to avoid increasing CO_2 emissions in electric power sector.