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Summary

Introduction

China is currently the largest CO\textsubscript{2} emitter in the world. The electricity sector plays a very important role in China’s carbon emissions growth. Whether the electricity sector can successfully improve electricity mix is related to the future of China’s carbon emissions targets. Therefore, there is an urgent need to develop low-carbon electricity (LE) technologies for electricity generation. Great efforts to develop LE have been made in China and great advancement has been obtained on hydro, nuclear, wind and solar power expansion. A substantial number of studies have explored the impact of LE development on the total carbon emissions in China. However, given the difference of economic development and resource endowments between regions in China, the carbon impact of LE development shows regional heterogeneity. Therefore, an obvious gap exists in systematically assessing the carbon impact of LE at the regional level, especially in terms of carbon emissions embodied in China’s exports. Moreover, there is a lack of investigation of the carbon impact of LE investments, which can further highlight the long-term potentiality of emission mitigations of LE development.

Research questions

From the above, we can deduce a number of issues. First, as many authors have shown, the structure of China’s energy system has enormous implications on the carbon embodied in the products and services produced and used in and exported by China. So, a study of the impact Chinese LE development on export-embodied carbon emissions should contribute to providing fundamental information for investigating export-embodied emission reduction potentials in China. Yet, few authors have taken into account LE developments from a regional perspective in China. A main reason for this is lack of detail in the electricity production sector in the available Chinese MRIO tables. However, this problem can be solved by a hybrid unit MRIO mode (see Chapter 3) and a final demand approach (see Chapter 4), as described above. At the same time a regional perspective is highly relevant, since the implementation of LE and the production of products and services for use in China and for exports are not at evenly distributed over the various Chinese regions. It is also appreciated that LE investments are usually more carbon intensive than investments in traditional electricity generation. As indicated, most scenarios do not take this factor into account (e.g. IEA, (2017)), let alone from a region-specific perspective. Against this background, this thesis aims to answer the following research questions:

1. How are carbon emissions distributed across sectors from the perspective of inter-sectoral linkages? What spillovers occur via supply chains, particularly between the electricity sector and other production sectors?

2. How will the development of low-carbon energy across regions impact carbon emissions embodied in China’s exports? What is the role of electricity transmission and supply chains in regional emission reductions?

3. How do the carbon emissions from investments in LE infrastructure compare to the reduction of carbon emissions during the use of LE? How are the carbon impacts of this infrastructure distributed within China?
4. How will the carbon impact from the expansion of LE infrastructure evolve in the future?

Answers to research questions

Answers to RQ1: Chapter 2 developed a subsystem input-output model to investigate the temporal and sectoral changes of multi-sectoral carbon emissions in China from 1997 to 2012. Comparing demand-induced carbon emissions with output-induced carbon emissions produced several useful conclusions. Moreover, the total carbon emissions were decomposed into four components: internal, spillover, feedback, and direct components. The results show that, the output-induced emissions of the electricity sector were largest, accounting for 40.1% and 49.3% of the total in 1997 and 2012 respectively, while the construction sector tended to have the largest demand-induced carbon emissions. The electricity sector was responsible for the outflows of carbon emissions, as the equipment manufacturing, construction and services sectors had a spillover effect on the carbon emissions in the electricity sector via inter-sectoral linkages.

Answers to RQ2: In order to attain information on the impact of LE on export-embodied carbon emissions, the Chapter 3 applied a hybrid, energy-economic, multi-regional input-output (MRIO) model of China and compared the observed LE development against a connatural scenario without LE expansion. A decomposition impact assessment framework was used to divide the total LE impact into three effects: intra-regional effect, electricity transmission effect, and supply-chain effect. The results show LE development reduced carbon emissions embodied in exports by 203 Mt (11.5% of the total carbon emissions embodied in exports), 244 Mt (14.9%), and 259 Mt (19.5%) in 2007, 2010 and 2014, respectively. Most important trade provinces in China, Jiangsu, Zhejiang and Guangdong, had the largest carbon emissions reductions. However, given the substantial hydropower development, some southwestern provinces (e.g. Sichuan and Hubei) had relative larger carbon impacts of LE than some major trade provinces (e.g. Hebei and Shandong). The exported electricity in the central and southwestern regions made a great contribution to reduce the carbon emissions in the eastern and southern regions via inter-regional electricity transmission and economic linkages.

Answers to RQ3: Many LE analyses neglected the impact of the expansion in LE infrastructure on carbon emissions. A demand-driven MRIO model was proposed in the Chapter 4 to estimate the carbon impact of LE investments at the regional level from both the intra-regional and inter-regional perspectives. Moreover, the carbon impact of LE investments was compared with the operational impact of LE development. The results show that the expansion of LE infrastructure increased net carbon emissions of 16.21 Mt, 28.71 Mt and 47.29 Mt in 2002, 2007 and 2010 respectively, even though the operation of LE was conducive to decreasing carbon emissions of 48.84 Mt, 81.83 Mt and 129.48 Mt per year. The magnitude of net operational impact of LE in the southwestern and eastern provinces was larger than that of net impact of LE investments. However, the decreased carbon emissions due to the operational impact of LE in several northern, northeastern and northwestern provinces cannot offset the increased carbon emissions due to LE investments. Moreover, the intra-regional effect of LE investments in the inland regions were large, while a large spillover effect could be found in the developed eastern region.

Answers to RQ4: The trend of cumulative installed capacity of LE in China have been projected by the well-known scenarios from national and international bodies. However,
the future carbon impact of LE development is influenced by the carbon impact of the expansion of LE infrastructure, as LE infrastructure tends to require more materials than fossil-fuel electricity generation technologies. In Chapter 5, the carbon overhead from LE infrastructure expansion was projected using available scenarios and experience curves of historical carbon intensity of LE installation. The projection shows that in all the scenario, the percentage of annual average carbon impact of LE investments in the China’s total carbon emissions will be less than 4% during 2015-2040. The carbon impact of LE investments in the all IEA scenarios will decline steadily during 2015-2040. Moreover, the carbon impact of LE investments in the NDRC-High Renewable Energy Penetration scenario will peak during the period 2030-2035, such that the carbon impact of LE investments in all scenarios will reach their lowest level during 2035-2040.

**Outlook**

The standard Chinese MRIO has a problem of low sector disaggregation, such that it is difficult to investigate the carbon impact of region-specific LE development in China. Moreover, neglecting the effect of electricity transmission results in omitting the transfers of LE impacts. These drawbacks are solved by a hybrid MRIO model, which links the LE generation in energy units to the Leontief matrix in monetary units and includes electricity transmission into the calculation of LE impact. The Chinese hybrid MRIO provides many options for further study (e.g. structural decomposition analysis). It also can be connected to global MRIO tables (e.g. EXIOBASE database). Therefore, future efforts could be made to analyze the impact of LE development on carbon leakage between China and specific developed countries in the context of global value chain.

Within a demand-driven MRIO model, the intra-regional impact and inter-regional impact of LE investments were used to show the differences in the regional pattern of the carbon impact of the expansion of LE infrastructure. However, the demand-driven MRIO model, which allocates the inputs of LE investments to the sectors existing in the MRIO table by constructing a demand vector, may induce a sector aggregation error. Therefore, further research is suggested to link detailed process-specific information to the MRIO model in order to improve accuracy of estimates.

The projection of the carbon impact of LE investments has risen policy implications for future LE development. However, experience curve induced a certain uncertainty, as the one-factor experience curve may be influenced by the future decline of the carbon intensity of electricity generation. Thus, for the future carbon impact of LE investments, the key question is whether the historical carbon intensity of electricity generation will be stable in the future. The answer to this question will depend on future operational impact of LE development on carbon emissions. Therefore, future research could give more insights into the ex-ante projections of operational impact of LE development.