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Variations of provincial CO_2 emissions under multiple perspectives in China

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ABSTRACT

China is a vast country with great regional variations in economy level, resource endowments, industrial structure, demographics, and CO_2 emissions level. Previous studies on regional CO_2 emissions were usually confined to production- or consumption-based perspectives and neglected the emissions under income-based perspective as they also can be enabled by the use of primary inputs. To fill this gap, we investigate the variations of provincial CO_2 emissions under these three perspectives in China during 2007–2012 and intend to identify out which type of final demand and primary input contributes most to the variations of provincial CO_2 emissions. Results show that variations of domestic outflow and gross fixed capital formation contributed most to the emissions growth for most provinces under consumption-based perspective, while variations of domestic inflow and compensation of employees did so under income-based perspective. This work can help guide the development of just and effective mitigation policies for various provinces in China.

Keywords: Production-based perspective, Consumption-based perspective, Income-based perspective, Input–output analysis, CO_2 emissions, Chinese provinces

1. INTRODUCTION

During the past decades, China has achieved rapid economic growth, which has dubbed the "China economic miracle". However, the development pattern heavily depends on the enormous resource depletion and energy consumption, which brings about conspicuous environmental pressures and burdens the sustainable development. China has become the largest emitter in terms of CO_2 emissions and pledged to reduce carbon emissions per unit GDP by 60–65% by 2030 from the 2005 level [1], from which the formidable challenge of balancing the environmental sustainability and economic growth can be seen for China.

The direct CO_2 emissions (a.k.a. production-based emissions) of a region can be driven by the final demands categorized by consumption, investment, and export, and allocate the environmental responsibilities to the final consumers (a.k.a. consumption-based emissions). Meanwhile, they can also be enabled by the primary inputs categorized by labor forces, capital, etc., and allocate the environmental responsibilities to the primary suppliers (a.k.a. income-based emissions) [2,3]. Most existing literature examined the emissions through production- or consumption-based emissions accounting principles [4,5] and overlooked the essential role of primary inputs in the supply chains. To tailor effective and just climate policies for economies, it is encouraged to explore CO_2 emissions under multiple perspectives [6].

China is a vast country with enormous regional differences in economic development level, industrial structure, resource endowment, demographics, and etc. [1], and the specific reduction targets of China are broken down to the provincial administrations. To fill the abovementioned research gap and support just and effective mitigation policies for each province, it is important to analyze CO_2 emissions at the provincial level under multiple perspectives. In this paper, the variations of provincial CO_2 emissions in China during 2007–2012 under production-, consumption-, and

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income-based accounting principles are comprehensively investigated and compared.

2. METHOD AND DATA

2.1 Production-, consumption- and income-based emissions accounting

The environmental extended input–output (EEIO) model is applied to investigate the production-, consumption- and income-based CO_2 emissions in this study. By taking the direct CO_2 emissions from each sector as the satellite account of this model, CO_2 emissions of an economy under multiple perspectives can be calculated [2,3], respectively, by Eqs (1)–(3):

$$e = fx \tag{1}$$

$$c = f\left(I - A\right)^{-1} y = fLy \tag{2}$$

$$d = v\left(I - B\right)^{-1} f' = vGf' \tag{3}$$

where *e*, *c*, and *d* indicate production-, consumption-, and income-based CO_2 emissions of an economy, respectively. The row vector *f* indicates the direct CO_2 emissions per unit output of each sector, the column vector *x* represents the total output of each sector. *I* is the identity matrix. *A* and *B* represent the local technical coefficient matrix and local allocation coefficient matrix, respectively, since we focus on the roles of local factors. Correspondingly, *L* and *G* represent the local Leontief inverse matrix and local Ghosh inverse matrix, respectively. The column vector *y* shows the final demands categorized by rural household consumption, urban household consumption, government consumption, gross fixed capital formation, changes in inventories, domestic outflow, and international export; the row vector *v* shows the primary inputs categorized by domestic inflow, international import, depreciation of fixed assets, compensation of employees, net taxes on production, and operating surplus.

2.2 Data sources

We collected the input–output tables for 30 provinces in China for the year 2007 and 2012 from Li et al. [7], and all the tables are in 42-sector format. Hong Kong, Macau, and Taiwan were excluded from this study due to lack of data. The first input–output table for Tibet is available for the year 2012, but it is not available for the year 2007. Therefore, we also excluded Tibet in this work. The provincial CO_2 emissions inventory by sectors were obtained from the China Emissions Accounts and Datasets (CEADs) [8]. To make the sector classification in input–output tables for these two years consistent with the emission data, we aggregated all the input–output tables in current producer's price and emissions inventory into 29-sector.

3. RESULTS AND DISCUSSIONS

The total direct CO_2 emissions (only includes emissions from industries but excludes household direct emissions) from the aggregation of 30 provinces increased from 6,548 Mt in 2007 to 9,096 Mt in 2012, with an average annual growth rate of 6.8%.

All the 30 provinces have experienced the direct CO_2 emissions increase except Beijing during 2007–2012. Inner Mongolia showed the largest increment of 269 Mt, with an average annual growth rate of 12.8%. Jiangsu, Hebei, and Shandong were the next three provinces with the largest emissions leap, all of them experienced increments over 160 Mt. There were additional six provinces underwent emissions growth over 100 Mt, they are Xinjiang, Anhui, Hubei, Shanxi, Sichuan, and Shaanxi. Beijing was the only province showing emissions decrease with an amount of 9 Mt.

3.1 Variations under consumption-based perspective

Fig 1 shows the variations of CO_2 emissions driven by different category of final demands of 30 provinces during 2007–2012. For Inner Mongolia, the variation of domestic outflow to the rest provinces within China drove the largest emissions growth, with a contribution of 227 Mt (69%). Inner Mongolia is a vast province with abundant coal resources, it domestically exports huge amounts of coal resources and electric power to surrounding provinces, the capital areas in particular, to support their economic activities. Gross fixed capital formation accounted for the next largest contribution to the emissions growth of Inner Mongolia under consumption-based perspective with an amount of 32 Mt (10%). This increment mainly emerged from the construction of infrastructures and buildings. The rest five types of final demand contributed the rest 10 Mt (3%) increment in total. Jiangsu and Hebei showed similar phenomenon that their emission increments were mainly driven by the growth of capital formation and domestic outflow, which jointly contributed 105 Mt (23%) and 120 Mt (24%) to the increments, respectively. The growth of capital formation drove consumption-based emissions increase by 130 Mt (20%) for Shandong, while the variation of domestic outflow decreased emissions by 60 Mt (-9%) that shows a big difference from other provinces. Besides Shandong, only domestic outflow variation of Guangdong decreased emissions among the rest 29 provinces. In general, variations of

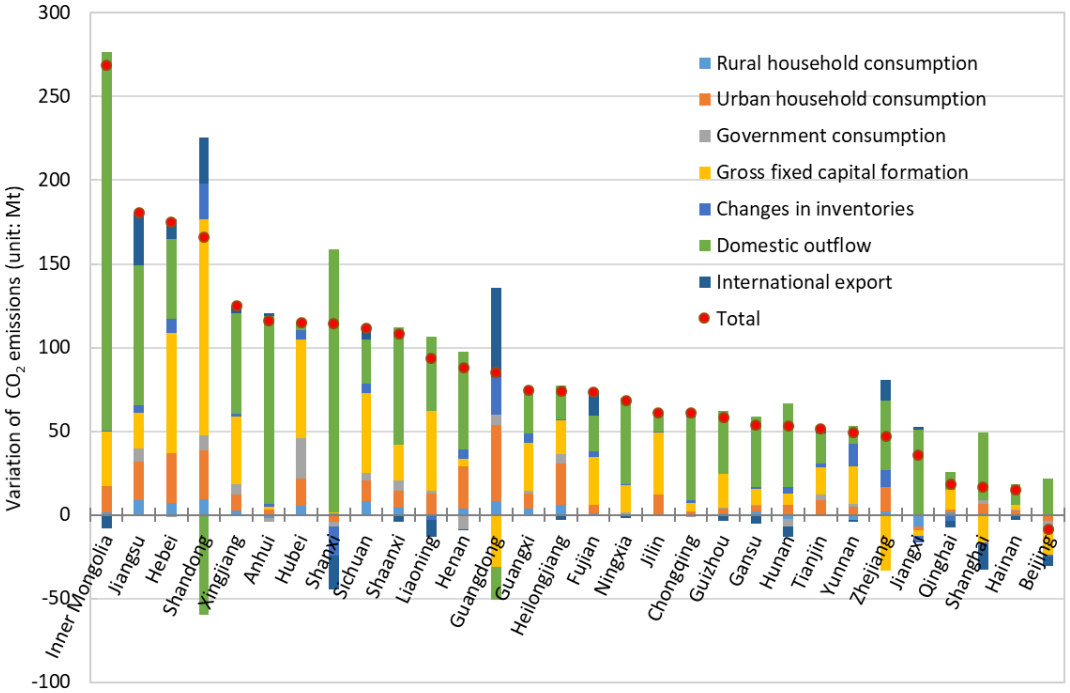

Fig 1 Variation of provincial CO_2 emissions under consumption-based perspective.

domestic outflow and gross fixed capital formation contributed most to the emissions growth for most provinces, and variation of international export decreased emissions for over half provinces, but their reduction effects were quite limited. Only the variation of domestic outflow drove consumption-based emissions growth for Beijing, while all the other final demand categories decreased emissions and made Beijing the only province underwent emissions reduction during 2007–2012.

3.2 Variations under income-based perspective

Fig 2 shows the variation of CO_2 emissions enabled by different types of primary input of 30 provinces during

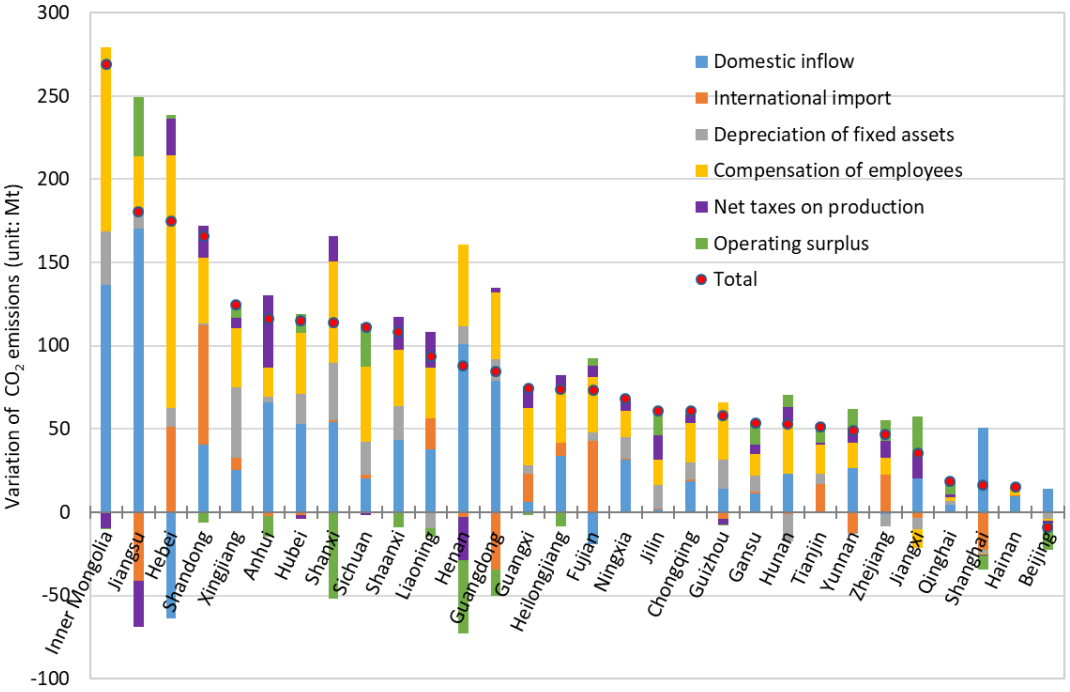

Fig 2 Variation of provincial CO_2 emissions under income-based perspective.

2007–2012. Variation of domestic inflow enabled CO_2 emissions growth in all provinces except Hebei, Fujian, and Zhejiang. Compensation of employees was another type of primary input that enabled great income-based emissions growth for all provinces except Jiangxi, Shanghai, and Beijing. For Inner Mongolia, the variation of domestic inflow enabled the largest income-based emissions growth with a contribution of 137 Mt (42%), followed by the increase enabled by compensation of employees (110 Mt, 34%). Most income-based emissions enabled by domestic inflow emerged from the electricity sector, which means this sector in Inner Mongolia domestically imported a great amount of electric power for production activities and then exported more domestically and internationally. Meanwhile, depreciation of fixed assets also enabled certain emissions growth during 2007–2012, and the other three types of primary input decreased income-based emissions with quite limited effects. The CO_2 emissions growth enabled by variations of both domestic inflow and operating surplus in Jiangsu were the largest among all provinces, with contributions of 171 Mt and 35 Mt, respectively. Meanwhile, variations of both international import and net taxes on production enabled the largest income-based emissions reduction in Jiangsu with effects of 41 Mt and 28 Mt, respectively. Variation of compensation of employees enabled the largest emissions growth in Hebei, with an amount of 152 Mt (29%), while domestic inflow offset the enabled emissions with a certain degree. Similar to the situation under consumption-based perspective, only domestic inflow enabled emissions growth for Beijing under income-based perspective, and this growth can be offset by the reduction effect enabled by operating surplus alone.

4. CONCLUSIONS

To formulate just and effective emission reduction policies and identify underlying reduction potentials, it is essential to investigate CO_2 emissions under multiple perspectives. This paper identifies out the key final demand categories under consumption-based perspective and key primary input categories under income-based perspective that contribute greatly to the CO_2 emission variations of 30 Chinese provinces during 2007–2012, respectively. Results show that all 30 provinces except Beijing experienced direct CO_2 emissions increase during the study period. Variations of domestic outflow and gross fixed capital formation drove most to the emissions growth for most provinces under consumption-based perspective, while that of domestic inflow and compensation of employees did so under income-based perspective. Only variations of domestic outflow and domestic inflow led to emissions growth for Beijing, respectively, under corresponding perspectives. This work provides the potential directions for emission reduction and can be helpful to guide the progress of tailored mitigation targets for various provinces in China.

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