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Temporal change in India's imbalance of carbon emissions embodied in international trade

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HIGHLIGHTS

- India's carbon emissions from 2000 to 2014 as producer and consumer.
- India's exported and imported emissions embodied in final and intermediate products.
- India's net-exported emissions increased rapidly after 2011.
- Optimizing the energy and trade structure in India can be effective.

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ABSTRACT

In India, rapid industrialization and reorganization of the global supply chain are driving economic growth, accompanied by increasing exports and carbon emissions. India is poised to succeed China as the next world manufactory, which will lead to huge emissions in the country. To formulate appropriate emission mitigation measures, it is necessary to further understand the temporal change in India's emissions at the sectoral level from both the production and consumption perspectives. However, existing studies that have estimated emissions in India have paid less attention to the link among original emitters, final producers and final consumers and to its temporal change. Based on an emission inventory compiled in this study, we trace emission flows from original emitters to final producers and then to final consumers through the international supply chain by using an environmentally extended multi-regional input-output model. This study finds that both production-based and consumption-based emissions in India increased constantly from 2000 to 2014, and production-based emissions had higher growth rates due to the increased coal share. The major receivers of India's exported emissions were developed countries (e.g., the European Union and the United States), while the main sources of India's imported emissions were developing countries (e.g., China and Russia). From 2011 to 2014, India's net exported emissions increased by 29.2% because of the decrease of imported emissions. Moreover, intermediate products (63% and 73.7%) were the major contributors to exported and imported emissions, most of which were embodied in manufacturing products (48.8% and 65.7%, respectively). Therefore, international cooperation to optimize the energy and trade structure and to improve energy efficiency can be effective in mitigating carbon emissions in India.

1. Introduction

Climate change has become one of the greatest environmental challenges that humans currently face [1,2]. Most carbon emissions in the atmosphere were emitted by anthropogenic activities [3], and the volume of emissions increased by 39.5% from 2000 to 2015 due to the

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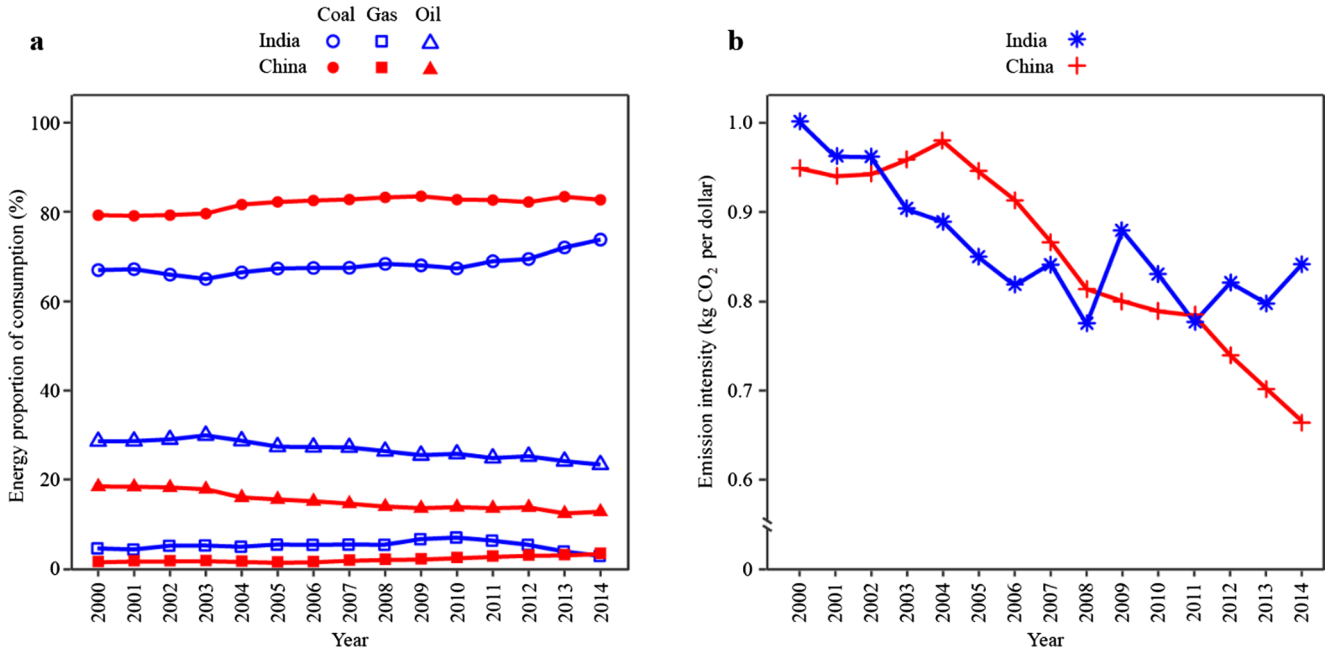

Fig. 1. Comparison of the emission circumstances in India (blue) and China (red). (a) Proportions of the emissions emitted by major energies. The data were obtained from a series of reports of CO_2 emissions from fuel combustion. (b) The trend of emission intensity, which represents carbon emissions per unit of economic output, was calculated using the emissions divided by the output adjusted based on the constant price for the year 2000. The data were calculated by the authors. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

increasing consumption of fossil fuels worldwide [4]. In response, the Paris Agreement established the goal of restraining the global average temperature to within 2 degrees above preindustrial levels, and the principles of equity and common but differentiated responsibilities were applied to mitigate emissions based on the capabilities of the signers [5].

As the second largest developing economy, India has a good baseline emission intensity (Fig. 1), which decreased from 1.0 kg per dollar in 2000 to 0.8 kg per dollar in 2008 because of the country's service-oriented economy, which features low emissions and high added value [6]. However, there was a substantial increase in emission intensity in 2009 due to the low energy efficiency caused by India's economic incentive policy in manufacturing [7,8], which will consume more energy than services for each unit of economic output. India's emission intensity was higher than that of China, and the gap between these intensities increased after 2011 as a result of the increasing proportion of coal consumption in India's energy mix. In response, India's government has committed its mitigation goals in its Intended Nationally Determined Contribution, which includes reducing the carbon emissions per-unit GDP from its 2005 level by 33–35% by 2030. This goal is less stringent than that of China (60–65%) for the same period [9,10].

These stricter environmental standards will encourage China to promote its industrial structure and to transfer its resource-intensive and labor-intensive products to countries with more relaxed environmental standards [11–13], and India will be poised to become the next world manufactory due to its loose environmental policy and low rent [14]. Emissions in China seem to have stabilized because of this reorganization of the global supply chain [15–17], and India's emissions will increase rapidly and continuously in the next several years [18–20]. To provide a scientific basis for designing effective mitigation measures to prevent India from becoming the next super emitter, it is necessary to further understand the temporal change in India's emissions at the sectoral level from both the production and consumption perspectives.

Two methods have been widely used to compile emission inventories: production-based and consumption-based accounting methods. Production-based emissions, which were utilized in the United Nations Framework Convention on Climate Change and the Kyoto Protocol, allowed a country to undertake the responsibility of emissions caused by domestic demand associated with exports without considering imports [21,22]. However, international trade has caused the geographic separation of producers and consumers and provided a path for producers to circumvent the responsibility of mitigating emissions by importing carbon-intensive products [23–25]. Under these circumstances, the consumption-based accounting principle, which stipulates that a country should undertake responsibility for its emissions, including domestic demand and imports but excluding exports, can be used to trace emissions to final consumers through the multi-regional supply chain and thus to avoid carbon leakage [26–28].

Many studies have compared these two accounting principles [29–31]. Under the production principle, developed economies (e.g., the United States and the European Union) can reduce domestic emissions by importing carbon-intensive products from developing economies (e.g., China and India), placing an unreasonable burden of responsibility on emerging economies [32–34]. If we applied the consumption principle, then developing countries would have a negative incentive to improve their low-carbon techniques because they would not need to shoulder the full responsibility for emissions; thus, this principle would be detrimental to the profits of developed countries [35,36]. Furthermore, researchers have calculated and compared the emissions resulting from the production and consumption principles at the global and national levels, and the findings illustrated that over the last two decades, developed economies have been net importers of emissions in international trade and developing economies have been net exporters because their products feature lower technologies and higher emission intensities [37–39]. The scale of emissions flowing from developing economies to developed economies increased from 2000 to 2011, with most of them embodied in intermediate products as a result of the deep convergence of the global economy [32,40,41].

Existing studies of the emissions embodied in India's international trade have provided a good starting point. Some researchers have estimated emissions based on India's input-output tables in 1991 and