ARTICLE IN PRESS

Energy Policy (xxxx) xxxx–xxxx

Contents lists available at ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

Actions on climate change, Reducing carbon emissions in China via optimal interregional industry shifts[☆]

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ARTICLE INFO

Keywords:
MRIO analysis
Carbon emissions
Industry structural change linear programming

ABSTRACT

This paper uses an optimal interregional input-output model to focus on how interregional industrial shifts alone might enable China to reduce carbon intensity instead of national shifts. The optimal industry shifts assure integration of all regions by regional services and goods in which carbon emissions are embodied via energy consumption. Generally speaking, high-tech industries should concentrate in affluent regions to replace construction. Selected services should increase output shares across most of regions. Meanwhile, energy-intensive manufacturing, rather than agriculture, should decrease their shares to achieve the national annual growth constrained by nation's carbon targets. Due to the need to decelerate energy use, carbon intensity goal puts particularly extreme pressure on less-developed regions to shutter heavy industries. Explicit shifts toward cleaner resources and renewable energy appear to be quite important for keeping coal mines in Central China working.

1. Introduction

China aims to cut its carbon emissions per unit of gross domestic product by 60–65% from 2005 levels by 2030, and intends to increase its share of nonfossil fuels as part of its primary energy consumption to 20% by the same date, according to its Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention for Climate Change (Intergovernmental Panel on Climate Change, 2007, China's Department of Climate Change, 2015). Regardless, China "will work hard" to assure its CO_2 emissions peak before 2030 (U.S. Energy Information Administration, 2014). This implies China must cut its carbon emissions by an annual average of about 4% for the remainder of this decade if its GDP of its economy continues to grow at 7% annually. In China, a strategy to abate regional carbon emissions is required to enable regional development goals. In light of this, energy conservation, investment in energy-efficient technologies, and shifts toward less-energy intensive industries are avenues to reducing carbon emissions. China's government ownership of large swaths of industry can make such structural shifts possible.[1]

"The impacts of climate change are felt most by those least responsible for the problem and with the least capacity to adapt." (Cultivating Equality, CARE, Food Tank, and CCAFS, 2015) Apart from agriculture, industry differences shape regions' abilities to adapt to the climate change. China's economy is diverse and interregionally integrated. Hence, its energy use and carbon emissions as embodied in interregional trade are important to recognize and understand. Indeed,

☆ The project was funded by (1) the National Social Science Foundation, Dynamic programming of the industrial structure shift towards a low-carbon economy based on a multiregional input-output model, Grant Agreement no: 10CJL033; (2) Key Grant of a project of National Social Science Foundation, Research on the Strategy of Low Carbon Development During China's Urbanization, Agreement no: 10zd & 032; (3) Key Grant of a project of National Natural Science Foundation, The Effect, Potential, Cost and Benefit Analysis on the Policy and Strategy of Low Carbon Agriculture, Forestry under the Background of Climate Change, Agreement no: 71333010; (4) by Recruitment Program of High-end Foreign Experts in the State Administration of Foreign Experts Affairs, Modeling The Relationship Between Green Household Gas Emissions (GHG) and Economy Structure, Agreement no:GDW20157200305; and (5) by Key Grant of the Project of Jiangxi Education Science Planning, Agreement no:15ZD3LYB005. (6) by the project of Jiangxi Regular Institution of Higher Education for the youth and middle aged oversea study development plan. This paper benefits from Dr. Zhipeng Tang in choosing asignificant subject, as well as providing much information and data, including a 2010 inter-provincial IO table. We are grateful for having discussions to thijs ten Raa, Erik Dietzenbacher, Xikang Chen, Bart Los, Klaus Hubacek, Kuishuang Feng, Xizhe Peng, Xingui Wang, Dr. Xia Yan, and Qin Zhu.

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[1] Indeed, the Central Committee confirmed the importance to China of re-investment, industry relocation, and productivity improvement across various industries while at the same time improving national energy efficiency (China Central Television, 2013).

http://dx.doi.org/10.1016/j.enpol.2016.10.038
Received 24 November 2015; Received in revised form 24 October 2016; Accepted 28 October 2016
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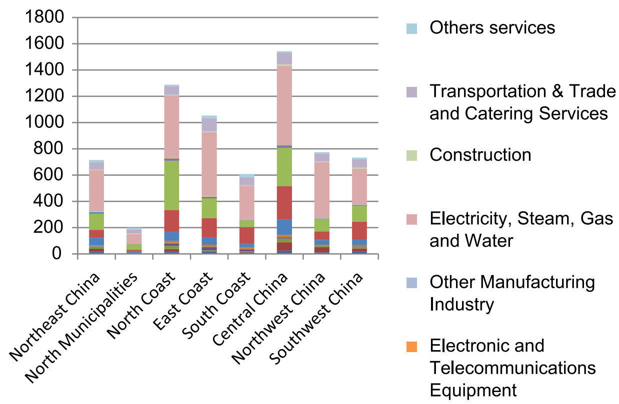
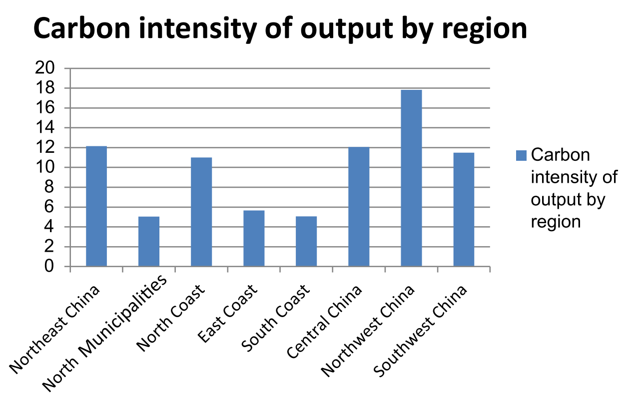
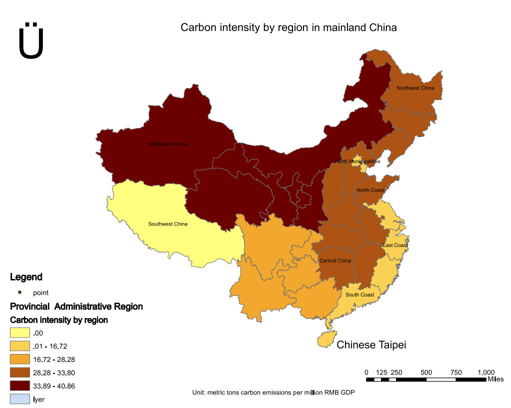


(a) Carbon emissions unit: 10 thousand metric ton



(b): Carbon coefficient unit: metric ton per million RMB output



(c)

Fig. 1. The quantity and intensity of regional and industrial carbon emissions. (a) Carbon emissions unit: 10 thousand metric ton. (b): Carbon coefficient unit: metric ton per million RMB output.

the regional focus of these resource and environmental elements are critical components of any national industrial strategy China might implement. It is by now fairly well known that China's less-developed regions discharge carbon emissions to enable consumption in and exports by the nations more-developed regions (Meng et al., 2013; Zhang and Lahr, 2014a). We describe the regional differences to demonstrate the importance of regional industry shifts. Fig. 1 has three parts, which respectively list (a) industrial emissions, (b) regional emissions, and (c) carbon emission intensity of output by region. The figure makes it clear that in 2007 the Central and North Coast regions produced the most carbon emissions—22.3% (160.9 million metric tons) and 18.6% (133.0 million metric tons), respectively. The Northern Municipalities and South Coast produce the least—3.0% (21.7 million metric tons) and 8.8% (63.7 million metric tons), respectively. In contrast, the intensity of carbon emissions is highest in the Northwest and Central regions (40.9 and 30.9 metric tons per million GDP RMB, respectively) and lowest in the North Municipalities and South Coast (14.9 and 15.5 metric tons per million GDP, respectively). For most regions, the carbon emissions are the greatest in Electricity, steam, gas and water and Smelting and pressing of metals, e.g., respectively, 59.8 and 29.4 million metric tons in Central and 42.5 and 9.6 million metric tons in Northwest. These figures include carbon emissions embodied in inputs as well as that used directly in the production process.[2]

Intuitively, substantial reductions in carbon emissions can be achieved by increasing the share of production in low-carbon, high value-added industries and by reducing the share of production in industries that discharge high levels of carbon and that yield relatively little value added.[3] Because industries use different amounts and types of energy resources and use different mixes of labor and capital across regions, China can improve its rate of GDP growth and meet carbon emissions targets by restructuring its industrial structure differentially across its regions.

Fig. 2 shows that Agriculture and Services both have large GDP shares and low carbon emissions shares.[4] Thus, setting regionwise industry adjustments or emission targets seems to be more appropriate than do nationwide equivalents to minimize exacerbation of any existing interregional welfare imbalances. We facilitate such an analysis here by implementing an interregional input-output table (ECEIRIO table) in a linear programming (LP) framework that constrains carbon emissions and energy use. The resulting model thus adds a special focus on the effects interregional trade in China, the political will alone to implement the changes could cause them to be achieved. A similar exercise for an economy that more fully embraces laissez-faire capitalism would be strictly an act of academic inquiry.

Identifying the drivers of carbon emissions and analyze effects of China's economic behavior on carbon emissions has been fairly heavily covered topic over the last decade (Guan et al., 2009; Weber et al., 2008; Feng et al., 2009, 2012, 2013; Peters et al., 2010; Minx et al., 2011; Zhang and Liu, 2014, Su and Ang, 2015; Zhang et al., 2016; Bin and Ang, 2015; Wang and Watson, 2007; Wiedmann and Barrett, 2013; Ferng, 2003). Modeling welfare outcomes of economies as constrained by available technology (Dorfman et al., 1958) has been less common. That is, until Xia (2010) and Wang et al. (2011) examined China's ability to meet its 11th five-year energy-savings targets. Yu et al. (2015) investigate China realize its energy-savings goal by adjusting its industrial structure based on a dynamic input-output model. Duchin et al. (2016) and Duchin and Levine (2016) collctively provide a contemporary body of conceptual, methodologi-

[2] The indirect carbon emissions in Eq. (3) and direct carbon emissions are calculated in the model, as discussed in Section 2. So the interregional output shifts through our model includes both direct and indirect carbon emissions.

[3] For example, certain manufacturing industries or finance services can more effectively lift labor productivity in Shanghai than they can in Central and Western China; while transportation services in Beijing discharge less pollutants due to usage of higher quality petrol than they do in Central and Western China, where coal remains the dominant energy resource.

[4] For example, Other services produces 22.4–47.4% of each region's GDP and releases between 1.1–7.6% of each region's carbon emissions. Energy-producing industries—like production and supply of electricity, steam, gas and water—discharge the largest shares of regional carbon emissions (from 36.6–54.8%) but generate quite small shares of GDP for every region (from 3–5%). For example, although it produces just 54.8% of all carbon emissions in the Northwest, the energy industry produces just 5% of the region's GDP. Heavy industries also discharge fairly great shares of each region's carbon emissions but attribute less to regionwide GDP. In the North Coast, smelting and pressing of metals & metal products releases 29.1% of all carbon emissions but yields just 6.7% of the region's GDP. In the South Coast, Nonmetal mineral products releases 21.2% of the region's emissions but contributes only 2.5% of the region's GDP.