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Zhu Liu

Carbon Emissions in China

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Zhu Liu

Carbon Emissions in China

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 Springer

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Supervisor's Foreword

By co-supervising Dr. Zhu Liu's Ph.D. Thesis, I'm pleased to introduce the influential and significant work by Dr. Zhu Liu. Dr. Zhu Liu contacted his doctor degree at the Chinese Academy of Sciences in 2009–2014 with the thesis topic of "Carbon emissions in China". Mitigating the human induced carbon emission is one of the most challenging issues facing mankind sustainable development. Dr. Zhu Liu's research about carbon emissions could have global impact on the carbon cycle of the earth system, climate change mitigation and human development.

In his Ph.D. Thesis, Dr. Zhu Liu conducted an analysis based on 4243 coal mines investigations and 602 site experiments to comprehensively test the carbon emissions from coal combustion in China. For the first time the "Measurable, reportable, verifiable" carbon emission factors and total carbon emission inventories are reported for nation, provinces, cities and individual sectors. Dr. Zhu Liu analyzed the feature, pattern and driving forces of China's carbon emissions. Results show that China's carbon emissions are mainly the result of fossil fuel combustion (90 %) and cement production (10 %). Manufacturing and power generation are the major sectors contributing to total carbon emissions, together these sectors accounted for 85 % of China's total carbon emissions. The results also uncovered significant differences in sectoral emission intensity among provinces, implying a huge disparity of technology level among regions. His study further explored China's emission embodied in international trade: the carbon footprints. By analyzing the carbon footprints by nations, Chinese trade represents 34 % of all emissions embodied in trade, and these traded emissions are growing each year. About twenty-five percent of China's carbon footprints are caused by manufacturing products that are consumed abroad. These results provide a basic understanding of China's carbon emissions and further propose a basis to support global mitigation efforts and low-carbon development.

Dr. Zhu Liu showed great insight, enthusiasm and critical thinking abilities during his Ph.D. study. He is always trying to find new approaches for his research. His strong quantitative background but openness to other approaches and his proven ability to publish in the top journals are clearly his most outstanding strengths, and demonstrate himself in establishing himself in academic field.

Sincerely yours

June 2016

Dabo Guan
Professor of Climate Change Economics
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Abstract

Anthropogenic climate change driven by human induced carbon emissions, is one of the most serious challenges facing human development. China is currently the world largest developing country, top primary energy consumer and carbon emitter. The nation releases one quarter of the global total (9.2 Gt CO₂ in 2013), 1.5 times that from US. Nearly three-quarters (73 %) of the growth in global carbon emission between 2010 and 2012 occurred in China. Without mitigation, China's emissions could rise by more than 50 % in the next 15 years. Given the magnitude and growth rate of China's carbon emissions, the country has become a critical partner in developing policy approaches to reducing global CO₂ emissions.

Supported by a 5-year joint research programme among more than 100 research institutes globally to investigate carbon emissions in China (Jiao and Stone, 2011), this study presents a systematically evaluation of China's carbon emission from fossil fuel combustion and cement manufacturing process. The main contributions of the study are listed as:

- (1) This study was conducted with 4243 mine investigation and 602 site experiments to comprehensively test the qualities of different fuels in China. For the first time the "Measurable, reportable, verifiable" carbon emission factors and total carbon emission inventories are reported for nation, provinces, cities and individual sectors.
- (2) The feature, pattern and driving forces of China's carbon emissions are analyzed. Results show that China's carbon emissions are mainly the result of fossil fuel combustion (90 %) and cement production (10 %). Manufacturing and power generation are the major sectors contributing to total carbon emissions, together these sectors accounted for 85 % of China's total carbon emissions. The results also uncovered significant differences of sectoral emission intensity among provinces, implying a huge disparity of technology level among regions. Less developed provinces with much higher energy intensive technologies, contribute to most of national emission increment since 2000s and cause the whole country's economic structure to become carbon intensive.

- (3) The study explored China's emission embodied in international trade: the carbon footprints. By analyzing the carbon footprints by nations, Chinese trade represents 34 % of all emissions embodied in trade, and these traded emissions are growing each year. About twenty-five percent of China's carbon footprints are caused by manufacturing products that are consumed abroad. These, so-called virtual emissions, which are "embodied" in international trade, lead to China having the world's most unbalanced virtual emissions trade with its emissions associated to exports being eight times higher than its emissions associated with imports.

This study provides basic understanding of China's carbon emissions and further proposes a basis to support global mitigation efforts and low-carbon development.

Keywords Sustainability · China · Climate change · Carbon Emissions · Carbon footprint

Parts of this thesis have been published in the following journal articles:

Zhu Liu, Dabo Guan, Douglas Crawford-Brown, Qiang Zhang, Kebin He, Jianguo Liu. Energy policy: A low-carbon road map for China. *Nature* 500, 143–145 (2013).

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Zhu Liu, Dabo Guan, Wei Wei, Steven J. Davis, Philippe Ciais, Jin Bai, Shushi Peng, Qiang Zhang, Klaus Hubacek, Gregg Marland, Robert Andres, Douglas Crawford-Brown, Jintai Lin, Hongyan Zhao, Chaopeng Hong, Tom Boden, Kuishuang Feng, Glen Peters, Fengming Xi, Junguo Liu, Yuan Li, Yu Zhao, Ning Zeng, and Kebin He. Reduced carbon emission estimates from fossil fuel combustion and cement production in China. *Nature* 524, 335–338 (2015).

Zhu Liu, Steven J. Davis, Kuishuang Feng, Klaus Hubacek, Sai Liang, Laura Diaz Anadon, Bin Chen, Jingru Liu, Jinyue Yan and Dabo Guan. Targeted opportunities to address the climate–trade dilemma in China. Targeted opportunities to address the climate-trade dilemma in China. *Nature Climate Change* 6, 201–206 (2015).

Zhu Liu, Soeren Linder, Yong Geng, Bing Xue, Fengming Xi, Ying Pan, TianZhu Zhang, Tsuyoshi Fujita. Features, trajectories and driving forces for energy-related GHG emissions from Chinese mega cites: The case of Beijing, Tianjin, Shanghai and Chongqing. *Energy* 37, 245–254 (2012).

Zhu Liu, Yong Geng, Soeren Linder, Dabo Guan. Uncovering China’s greenhouse gas emission from regional and sectoral perspectives. *Energy* 45, 1059–1068 (2012).

Zhu Liu, Yong Geng, Soeren Linder, Hongyan Zhao, Tsuyoshi Fujita, Dabo Guan. Embodied energy use in China’s industrial sectors. *Energy Policy* 49, 751–758 (2012).

Dabo Guan, **Zhu Liu**, Yong Geng, Soeren Lindner, Klaus Hubacek. The gigatonne gap in China’s carbon dioxide inventories. *Nature Climate Change*, 672–675 (2012).

Kuishuang Feng, Steven J Davis, Xin Li, Dabo Guan, Laixiang Sun, Weidong Liu, **Zhu Liu**, Klaus Hubacek. Outsourcing CO₂ within China. *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 110, 11654–11659 (2013).

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