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Exploring the impacts of a low-carbon policy instrument: A case of carbon tax on transportation in China

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ABSTRACT

The rapid growth of energy consumption and CO_2 emission in transportation has brought great challenges to China's energy demand and environmental issues. Carbon tax, considered as an efficient low-carbon policy instrument, can effectively reduce the use of fossil fuels and improve energy efficiency. This study aims to explore the impacts of a transportation carbon tax on transport sectors, macroeconomy and social welfare by developing a computable general equilibrium (CGE) model. Meanwhile, to achieve fiscal revenue neutrality, two schemes are employed for revenue recycling. One is that all of the carbon tax revenue is recycled to subsidize households through lump-sum transfer; the other one is that carbon tax revenue is used to reduce the income tax of households and enterprises. The simulation results show that the appropriate carbon tax rate is 50 Chinese Yuan (RMB)/ton-CO_2. At this level of taxation, energy demand and carbon reduction have fewer negative impacts on the macro-economy and transport sectors. We also find that the appropriate carbon tax rates among different transport sectors and different energy categories are different. The appropriate carbon tax rates for airlines, railway, urban transport and water transport are same (50 RMB/ton-CO_2), while the appropriate carbon tax rate for road transport sector is 60 RMB/ton-CO_2. The recycling of carbon tax revenue to households and enterprises should be implemented to realize the "weak double dividend" effect of the carbon tax.

1. Introduction

Global warming poses a fundamental threat to natural ecosystems and economic development (Parmesan and Yohe, 2003; Gleick et al., 2010). There is a scientific consensus that anthropogenic greenhouse gas (GHG) emissions have contributed significantly to global climate change (IPCC, 2007). Carbon dioxide (CO_2) emissions account for 72% of total GHG emissions, which is considered as the most important cause of global warming. With the rapid growth of its economy, China has become the largest carbon emitter (Liu et al., 2017a,b). According to the Carbon Budget Report 2016, total carbon dioxide emissions in China were 10.4 billion tons, accounting for 29% of global emissions and exceeding the sum carbon emission of the United States and 28 countries in the EU (GCB, 2016). Under this circumstance, the Chinese government has committed to reduce its carbon dioxide emissions per unit gross domestic product (GDP) by 60–65% from the 2005 level by 2030 (Tian et al., 2017).

CO_2 is generated by burning energy like coal, natural gas, diesel, and gasoline, among others. It is recognized that transportation is a typical energy-dependent industry and has made an important contribution to the rapid development of the Chinese economy (Li et al., 2017). However, this rapid development in transportation industry also resulted in excessive resource consumption and increasing environmental pollution and carbon emissions. According to Annual Review of Low-Carbon Developing in China (2017), in 2015, total CO_2 emissions from energy consumption in China declined by 0.6%, while CO_2 emissions of the transportation industry still show a growing trend. Moreover, in recent years, the serious haze weather in China is blamed to rapid development of transportation (Yu et al., 2013). Some scholars even suggest that China's atmospheric pollution results from the motor vehicle pollution (Cao et al., 2012; Ding, 2016). Under energy and environment pressures, how to develop low-carbon transportation while maintaining stable economic growth poses a serious challenge for the transportation industry in China.

Implementing a carbon tax provides a practical and efficient measure to reduce carbon emissions and has been adopted by various countries, including Sweden, Norway, the United Kingdom, Denmark, Finland, Japan, France, Germany, and others. Their experiences suggest that carbon taxation plays an important role in carbon emissions reduction (Pigou, 1920; Al-Abdullah, 1999; Zhang and Baranzini, 2000;

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Wallace, 2011; Fedor, 2016). Nakata and Lamont (2001) employed a partial equilibrium model to examine the impacts of carbon tax on energy systems in Japan and found that CO_2 emission decreased after implementing a carbon tax. A research by Shakya et al. (2012) demonstrated that carbon taxation might be an efficient policy to reduce carbon emissions. Bureau (2011) indicated that a carbon tax is an effective option for easing the traffic pressure and reducing carbon emission. Rausch and Reilly (2012) also found that a carbon tax would provide a "Win–Win–Win" solution to US. Despite implementing carbon taxation is an effective option for reducing energy consumption and superior carbon mitigation, it also results in a negative impact on GDP, the investment, consumption and welfare of household groups (Babiker et al., 2003; Wissema and Dellink, 2007; Callan et al., 2009; Joglekar, 2009). Therefore, some strategies were employed to compensate the negative impacts of carbon tax on economy, like tax revenue recycling schemes (Liu and Lu, 2015) and a suitable carbon rates (Sumner et al., 2011). McKibbin et al. (2012) explored different uses of tax revenue on the economy-wide mitigation cost and fiscal position for US. Their results showed that using a carbon tax to reduce capital taxes would expand the overall economy and short-run employment. A study by Zhang and Baranzini (2000) showed that carbon tax may be an interesting policy option and that their main negative impacts may be compensated through the design of the tax and the use of the generated fiscal revenues. Beck and Wigle (2014) and Bohringer and Müller (2014) also suggested that the negative impacts of a carbon tax can be largely reduced if the tax revenue was used to reduce corporate or income taxes. In order to seek complementary carbon taxation, Chinese government should learn the lessons from the other countries' experiences and balance the benefits and disadvantages between economic development and environmental protection.

As the largest developing country and carbon emitter, China is facing the challenge to respond to GHG emission mitigation and draw up to an appropriate carbon tax in transportation industry. Currently, there is an increasing number of studies that have explored the impact of a carbon tax on the Chinese economy using CGE model, which has been widely applied to assess the economic and environmental impacts of carbon tax issues (Lu et al., 2010; Carrera et al., 2015; Liu et al., 2017a, 2017b; Tang et al., 2017). For example, Dai et al. (2012) explored the impact of China's household consumption expenditure patterns on energy demand and carbon emissions over the period 2005–2050. Guo et al. (2014) applied a CGE model to investigate the impacts of a carbon tax on China's economy and carbon emission. Most of these studies employed the same carbon tax rate to all provinces and industries, which might result in an unfair deal due to neglecting the disparities among different provinces and industries. In this regard, some scientists started to focus on provincial disparities. Dong et al. (2017) developed a 30-Chinese-province CGE model to conduct the provincial evaluation. Their results suggested Chinese government to allocate different carbon reduction targets in different provinces, and carbon price should be no more than 50 USD/ton. Weng et al. (2018) analyzed the economic impacts the economic impacts of the differentiated CO_2 intensity targets between Guangxi Province and the rest of China and showed different CO_2 intensity targets in different regions will affect Guangxi's GDP, carbon price, welfare and output. Since the transportation industry includes different sectors with various characters, it is important for Chinese government to allocate the appropriate carbon reduction measures to all the sectors. However, no relevant studies take the disparities among various sectors within transportation industry into account when they attempt to draw up to a carbon taxation. Therefore, our study aims to employ a CGE model to explore the effects of different carbon rates on various transport sectors with different energy utility characters and macroeconomy, and to assess the impact of tax revenue recycling schemes on macroeconomy and welfare. The specific objectives of this study are to answer the following research questions:

1) What are the effects of different carbon tax rates on the transportation industry?
2) what are the effects of different carbon tax rates on the different transport sectors?
3) How could tax revenue recycling schemes reduce the negative impacts of carbon tax on the macroeconomy and social welfare?

The paper is organized into 5 sections. Following this introduction section, Section 2 introduces the energy and carbon emissions situation of China. Section 3 explains the CGE model and the dataset used in this paper. Discussion on the results is demonstrated in Section 4. Finally, conclusions are drawn in Section 5.

2. Energy and carbon emission situation in the China's transportation

2.1. Energy consumption in transportation

Fossil energy (coal, petroleum and natural gas) and electricity play important roles in China's transportation energy structure. Oil mainly refers to refined petroleum, including gasoline, diesel, kerosene, fuel oil and other oil products. In recent years, the growth rate of energy consumption in the transport sector has exceeded the growth rate of total energy consumption.

In Fig. 1, energy consumption in the transportation industry grew faster than the total energy consumption in China. In 1995, transportation energy consumption was 58.63 million tons of standard coal, accounting for 4.47% of total energy consumption. In 2015, traffic energy consumption increased to 383.17 million tons of standard coal, which accounts for 8.91% of China total energy consumption. The energy consumption increased by 5.54 times during the last 20 years.

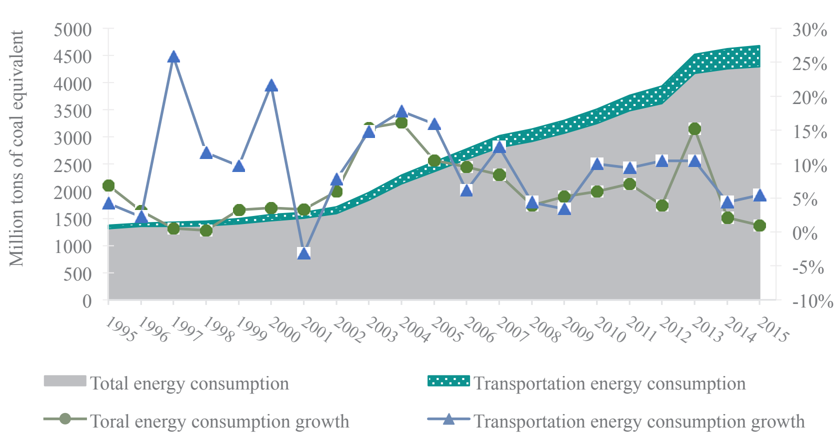

Fig. 1. Energy consumption in China, including transportation industry.