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Exploring impact of carbon tax on China's CO_2 reductions and provincial disparities

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ABSTRACT

With fast development, it is not easy for China to achieve carbon reduction targets only by traditional command and control measures (e.g., the measures for energy-efficiency). Carbon tax is advocated as one effective complementary measure and has high possibility to be implemented for China's future low carbon development. Under such a circumstance, this paper aims at forecasting the possible impact of carbon tax on both carbon reduction and economic loss of 30 Chinese provinces. A 30-Chinese-province CGE (Computational general equilibrium) model has been developed to conduct the provincial evaluation, and seven scenarios including Business-as-Usual (BaU) scenario and six carbon tax scenarios with carbon price from 20 USD/ton to 120 USD/ton up to 2030 are set. The results show that China's industrial CO_2 will be reduced from 12.2 billion tons under BaU scenario to 10.4 billion tons, 9.3 billion tons, 8.5 billion tons, 7.9 billion tons, 7.4 billion tons and 7.0 billion tons under scenarios of TAX20, TAX40, TAX60, TAX80, TAX100 and TAX120 in 2030, respectively. Electricity, Metal and Chemicals sectors have high reduction potentials and are priority sectors for carbon tax policy. Provincial disparity analysis demonstrates that coal production/consumption and total energy consumption are key factors to affect carbon tax effect on CO_2 reduction, and Inner Mongolia, Shandong, Shanxi and Hebei have the largest industrial CO_2 reduction potentials after levying carbon tax. However, the implementation of carbon tax will impede economic development for all provinces. Therefore, the concept of carbon tax efficiency is further proposed in order to evaluate the effectiveness of carbon tax by considering both CO_2 reduction and GDP loss. Policy suggestions indicate that provinces of Shanxi, Inner Mongolia, Hebei and Anhui should be set priority when implementing carbon tax policy in China, and carbon price should be no more than 50 USD/ton.

1. Introduction

China is facing an increasing pressure to curb greenhouse gas (GHG) emissions since it surpassed the US and became the largest carbon emitter in 2007 [1,2]. In order to respond such a challenge, the Chinese government committed to reduce the intensity of carbon dioxide emissions per unit of GDP in 2020 by 40–45% compared with the level of 2005, and to increase the share of non-fossil fuels in primary energy consumption to approximately 15% by 2020 [3–5]. Considering that China is undergoing fast industrialization and urbanization, the Chinese government realizes that it may not be easy to achieve carbon reduction commitment if only traditional command and control measures (e.g., the measures for energy-efficiency) are used [6]. Thus, it is necessary to introduce market-based emission reduction measures such as carbon tax and carbon trading.

In 2013, China's National Development and Reform Commission (NDRC) launched its "pilot emission trading scheme" in seven provinces and cities [7,8]. Chinese President Xi Jinping further announced in September 2015 that China would launch a national cap-and-trade scheme in 2017 [9]. As for carbon tax policy, NDRC and the Ministry of

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Finance (MOF) had also issued their joint special report, proposing that a carbon tax should be levied in China around year 2012 [10]. However, it was postponed due to many reasons. Economists and international organizations have long advocated carbon taxes because they are easier and can generate larger carbon emission reduction with less negative impact on economic growth [11–13]. Moreover, the carbon trade scheme is a complicated and long process that cannot effectively respond current environmental problems, particularly the serious haze weather [14]. It is particularly critical to promote such a tax in China since China is facing serious challenges on responding climate change and promoting energy saving and emissions reduction [15,16]. Therefore, considering the advantages of the policy itself and the possibility of being implemented in the near future of China, this study examines the impact of future carbon tax on China so that useful policies can be released to guide its future carbon tax implementation.

Carbon tax targets to levy tax on fossil fuels (such as coal, oil, natural gas) according to their carbon contents or their carbon emissions from combustion [17]. It is an incentive-based policy instrument for controlling the carbon dioxide emissions and has received global attentions since early 1990s [18,19]. The ultimate objective of such a tax is to mitigate climate change by increasing the cost of fossil fuel usage. The implementation of this policy will result in a demand shift from carbon intensive fuels to "clean energy" (a process of optimization in energy mix) and also an industrial structure shift from energy intensive production to knowledge or service based economy [20]. The collected tax could be used to support the development of renewable energy by subsidizing the environmental protection projects or the technological development of energy saving and emission reduction [13].

Several studies have been done to evaluate the effect of carbon tax on China's economic development, carbon reduction, living standard, social welfare, et al. For example, Liu and Lu investigated carbon tax impact on China's economy using a dynamic CGE model, namely the CASIPM-GE model, and results showed that the carbon tax was effective to reduce carbon emissions with minor impact on China's macro economy [21]. Liang and Wei [10] adopted a recursive dynamic CGE model to explore the impact of a carbon tax on the urban–rural gap and living standard, and found that the implementation of carbon tax under the current social welfare system would increase the income gap between urban and rural households. Li et al. [22] found that a uniform carbon tax may impede the economic development in less developed regions but will promote economic development in the more developed coastal areas. Wang and Yan [15] investigated the impacts of carbon tax on Chinese economy, energy saving and carbon emissions reduction by using one CGE model and concluded that lower carbon tax is a feasible choice under current economic situations. Yang et al evaluated the potential of China's carbon tax policy in CO_2 mitigations from the perspective of inter-factor/inter-fuel substitution and found that nearly 3% reduction in CO_2 emissions from the 2010 level can be achieved by levying a carbon tax at 50 Chinese Yuan (RMB)/ton, particularly in the areas of East coast and Southwest China [20]. Zhu et al. investigated the impact of carbon tax on different Chinese industrial sectors and concluded that carbon tax has different impacts on different economic sectors and higher emission sectors may suffer from such a policy [23]. In addition, Zhang and Li further confirmed that carbon tax would stimulate economic development in most eastern regions but may have negative impacts on the economic development in the middle and western regions [24].

However, these published studies mainly focus on the whole China or one province or different regions. Since China is a very large country with imbalanced economic development, different resource endowments and technological levels [25], it is necessary to uncover the provincial disparities of carbon tax effect on both economic development and carbon reduction so that key provinces for carbon tax implementation can be recognized. Therefore, the main objective of this study is to predict future carbon tax impact so that valuable carbon tax policies can be raised to guide China's low carbon development. A 30-Chinese-province CGE model has been developed for such a provincial evaluation. The whole paper is organized as below. After this introduction section, Section 2 presents the research methods, including a detailed introduction on the new 30-Chinese-province CGE model and scenarios setting, as well as data collection and treatment. Section 3 describes the research results on future industrial CO_2 reduction potentials for different industrial sectors and provinces under different carbon tax scenarios. Section 4 discusses policy implications with a special attention on carbon tax sensitivity and provincial carbon tax efficiency. Finally, Section 5 concludes the whole study and provides reasonable policy recommendations for implementing carbon tax in China.

2. Methodology and data

2.1. The 30-Chinese-province CGE model

The CGE model stems from the general equilibrium theory of Walras, in which it demonstrates that supply and demand are equalized across all of the interconnected markets in the economy. It combines the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve for the levels of supply, demand and price that support equilibrium across a specified set of markets [26]. The CGE model is widely used in analyzing impacts of policies such as taxes, subsidies, quotas or transfer instruments [27–30]. It is also a popular tool for the analysis of long-term economic implications of climate change policy [7,31–33].

The 30-Chinese-province CGE model developed in this study can be classified as a multi-sector, multi-region, recursive dynamic global CGE model that covers 22 economic commodities and corresponding sectors, and eight power generation technologies. Table A1 in supporting material shows all the details. The major model features are similar to the one-region version [34], including a production block, a market block with domestic and international transactions, as well as government and household income and expenditure blocks. Activity output for each sector follows a nested constant elasticity of substitution (CES) production function. Inputs are categorized into material commodities, energy commodities, labor, capital and resources. The technical formulation of the 30-Chinese-province CGE model has been detailed in [35], and summarized in the supporting materials. One special feature of this model is that the number of modeling regions, both internationally and within China, is highly flexible to allow for a wide range of studies. In this regard 3 regions, 7 regions or 30 provincial units of China and 1, 3, or 14 international regions could be analyzed consistently, as summarized in Table A2 in the supporting material. Tibet, Hong Kong, Macau and Taiwan are not included due to the lack of data. This CGE model is solved by the software of MPSGE/GAMS (Mathematical Programming System for General Equilibrium under General Algebraic Modeling System) [36] at a one-year time step. It has been used intensively for assessing China's climate mitigation at the national [37] and provincial levels [2,7,37–42].

2.2. Data sources

Most of the global data in this CGE model are based on the database of Global Trade Analysis Project (GTAP) 6 [43] and International Energy Agency (IEA) [IEA, 44]. The specific Chinese provincial data are based on the 2002 inter-regional input-output tables (IOT) [45] and the 2002 energy balance tables (EBT) [46]. In addition, carbon emission factors, energy prices for coal, oil and gas, and renewable energy technology costs are also required parameters. All the datasets are converted to the base year of 2002. Moreover, it is well-known that IOT and EBT are inconsistent when it comes to energy consumption across sectors, and the energy data from EBT is regarded as more reliable than IOT. A novel characteristic of this CGE model is that the