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A general equilibrium assessment of economic impacts of provincial unbalanced carbon intensity targets in China

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ABSTRACT

It is necessary to measure the economic impacts of the attempts to achieve China's carbon emission intensity reduction target. Consequently, this study analyzes the economic impacts of the differentiated CO_2 intensity targets between Guangxi Province and the rest of China. An improved two-region computable general equilibrium model with eight scenarios is used. Our results show that different CO_2 intensity targets in different regions will affect Guangxi's GDP, carbon price, welfare, and output. The highest reduction target of 75% in the P75C65 scenario in Guangxi will lead to a cost of 0.42% in per capita GDP loss, 0.51% of welfare loss, and a carbon price of 49.4 USD/t. In addition, the output of the energy-intensive sectors is most vulnerable to carbon mitigation policy. The two mechanisms that affect economic indicators are price and scale effects. Under the P75C65 scenario, sectors such as vehicle manufacturing are winners and are affected by both price and scale effects in Guangxi, with export, provincial outflow, domestic supply, and output decreasing by 1.64%, 0.88%, 0.93%, and 0.93%, respectively. In contrast, sectors such as agriculture are losers and are affected by the scale effect, with these four indicators increasing by 1.25%, 0.97%, 0.59%, and 0.73%, respectively. These findings provide valuable insights for policy makers who wish to allocate provincial reduction targets and achieve co-benefits between the economy and the environment.

1. Introduction

China has already surpassed the United States as the world's largest carbon emitter, and its emissions are likely to continue to rise rapidly in line with its industrialization and urbanization (Dai et al., 2011). To achieve mitigation responsibility, China has been making great efforts to cut emissions and jointly address the problem of climate change, even since the withdrawal of the United States from the Paris Agreement (Zhang et al., 2017; Dai et al., 2017). China has established a carbon intensity target in its 12th Five-Year Plan (2010–2015) (NBS, 2017), which proposed Intended Nationally Determined Contributions (INDC) to lower CO_2 emissions per unit of GDP by 60–65% from the 2005 level by 2030 (NDRC, 2015). However, it is still challenging to disaggregate these targets into provinces by considering economic impacts.

A number of studies have tried to analyze the burden sharing of carbon reduction. Some researchers have focused on the allocation among different countries. For example, Persson et al. (2006) put forward an allocation method that is based on equal per capita or contraction and convergence for developing countries. Böhringer and Lange (2005) proposed two kinds of allocation rules for dynamic grandfathering schemes in an open or a closed trading system in EU ETS. Meanwhile, some researchers have focused on the allocation among different provinces in China. For example, Wang et al. (2013) proposed an efficient emission allowance scheme at the provincial level based on a zero-sum gains data envelopment analysis model. Yi et al. (2011) proposed a CO_2 emission intensity allocation model to disaggregate reduction targets into provinces. Additionally, other studies paid attention to industrial sectors (Yang et al., 2017; Cai et al., 2008; Wang and Liang, 2013; Chen and He, 2014; Xia and Chen, 2012; Wrake et al., 2012; Chen et al., 2017). Most of these studies investigated allocation of carbon intensity based on the principle of equity (He et al., 2009; Ringius et al., 2002; Miketa and Schrattenholzer, 2006; Ding et al., 2009), efficiency (Wang et al., 2012; Choi et al., 2012), and

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several other approaches (Hong et al., 2014; Jiang et al., 2016; Oestreich and Tsiakas, 2015; Perthuis and Trotignon, 2014).

From the economic impacts perspective, most previous studies have estimated the economic cost through GDP loss or welfare loss based on Copenhagen and NDC carbon intensity targets. For example, Zhang et al. (2013a) developed a static Computable General Equilibrium (CGE) model with global coverage that disaggregated China's 30 provinces and energy system to assess the impacts of provincial CO_2 emissions intensity targets. Wang et al. (2015) analyzed the economic impacts among four energy-intensive sectors to achieve the Copenhagen target in Guangdong province, China, and found that the current mitigation policy that is implemented in China would have moderate negative economic impacts (i.e., GDP or welfare loss of 0.8%–3.5%). Cui et al. (2014) focused on the cost-saving perspective to measure the costs with or without carbon ETS based on China's 2020 carbon intensity reduction target. Their results indicate that a dramatic reduction of abatement costs of approximately 23.67% would be achieved under the unified ETS scenario. Wu et al. (2016) found that Shanghai's GDP loss would be 1.7% in 2030 in the ETS scenario, following the target of INDC as the carbon intensity target. Xie et al. (2018) found that the GDP loss would be 0.68% (36.92 USD per capita) in Tianjin, 0.56% (106.77 USD per capita) in Beijing, and 0.55% (19.35 USD per capita) in Hebei under the relative higher tax scenario. However, Li et al. (2018) found that there was a 5.54% GDP loss in the highest carbon tax scenario. The environmental and economic impacts on specific industries and industry chains have also been estimated (Liu and Lin, 2017; Wang et al., 2017; Zhang et al., 2016; Tang et al., 2017).

Although plenty of studies have investigated the disaggregation of carbon reduction into sub-nations, very few have explored the economic impacts. Meanwhile, the few studies of the economic impacts of carbon reduction have only considered the effects of carbon intensity under uniform standard at the national or regional scale, while the marginal cost of carbon reduction may vary widely across provinces. Alongside economic growth and environmental protection, promoting inter-regional equity is still one of the leading priorities of China's policymakers (Zhang et al., 2013b). Consequently, provincial-disaggregated allocation and the related economic assessment of the reduction target are necessary. Moreover, industrial competitiveness under provincially differentiated carbon reduction targets should also be studied to ensure the normal development of the regional economy (Lu et al., 2010; Tian et al., 2017).

Given these concerns, the two research regions that will be used in this study are Guangxi Province and the rest of China (ROC). The following three research objectives will be investigated: 1. Assess the economic impacts of provincially differentiated carbon reduction targets; 2. Investigate the competitiveness of typical industries in Guangxi Province under different carbon reduction situations; 3. Provide policy suggestions that are based on the results of differentiated reduction targets between Guangxi Province and the ROC.

The rest of this paper is structured as follows. Section 2 describes the research area of Guangxi Province. Section 3 introduces the CGE model, the data, and the scenario assumption. Section 4 describes the results. Section 5 discusses the policy implications, limitations and future work. This paper concludes with our final remarks in Section 6.

2. Research area

Guangxi is located in the southern part of China (Fig. 1). It has a total area of 236,700 km^2 and in 2016 it had a permanent population of 48.4 million. In 2016, Guangxi Province's GDP was 1,824.5 billion yuan, ranking 18th among 31 provinces in China. Consequently, Guangxi belongs to the less-developed provinces of China. Approximately half of the GDP was contributed by secondary industry (47%), while tertiary industry share was 45.8% and agriculture was only 7.2% (Moellendorf, 2011). The urbanization rate was 48.1% less than the national average level (57.4%). As an important minority autonomous region, it is of significant importance for Guangxi Province to realize the national goal of establishing a moderately well-off society by 2020. In 2013, President Xi Jinping proposed alleviating poverty as a national strategy. In Guangxi Province, 4.52 million people (or around 10% of the population) live below the poverty line, accounting for 6.5% of total poverty number in the 13th Five-Year Plan phase. Therefore, it is becoming increasingly important to comprehensively consider the economic impacts of achieving the carbon reduction target, especially for less-developed areas.

Guangxi has a critical strategic role to play in the Belt and Road Initiative. Guangxi shares land borders with Vietnam, and it is situated in a key geographical position in terms of China's land connections with Southeast Asia. For example, many of the ports in Guangxi's Beibu Bay Economic Zone offer considerable room for the development of sea connections.

The special economical and geographical characteristics of Guangxi suggest that more attention should be paid to Guangxi to enhance synergy rather than making trade-offs among the various existing national strategies, such as carbon mitigation policy, poverty alleviation, and the Belt and Road Initiative. Additionally, ROC, which represents the average level of China, was set to make a comparison with Guangxi Province in the CGE model. Analysis of the economic impacts for Guangxi Province and ROC could help provide some political recommendations.

3. Methodology

3.1. The CGE model

The CGE model can capture the full range of interaction and feedback effects among different agents in the economic system. It has been widely used to assess the economic and environmental impacts of different climate policies at global (Böhringer and Löschel, 2005; Fujimori et al., 2015) and national (Wang et al., 2009a; Fujimori et al., 2014) levels. The Integrated Model of Energy, Environment, and Economy for Sustainable Development|Computable General Equilibrium (IMED|CGE) model that is applied in this study is a multi-sector, multi-region, recursive dynamic CGE model that has been continuously developed by College of Environmental Science and Engineering at Peking University.

As a two-regional dynamic CGE model, this model includes two regions of Guangxi Province (GX) and the ROC (Dai, 2012). This is a much better tool than a one-region model to study low-carbon economy because Guangxi's economy is closely interlinked with the ROC through commodity trade, immigration, and cross-boundary investment. Moreover, this study uses a dynamic model rather than a static model because a dynamic model is able to more realistically depict the chronological process of economic development. For example, it includes the process of capital accumulation and corresponding technology improvement.

The CGE model can be classified as a multi-sector, multi-region, recursive dynamic CGE model that covers 25 economic commodities and corresponding sectors (Table 1), which are classified into basic and energy transformation sectors. The features of this model are similar to the one-region model (Dai, 2012), including a production block, a market block with domestic and international transactions, in addition to government and household income and expenditure blocks. The output of the activities for each sector follows a nested Constant Elasticity of Substitution (CES) production function. The inputs are categorized into material commodities, energy commodities, labor, capital and resources. The supply of commodity adopts the Armington assumption, which assumes that the goods produced from other provinces and abroad are imperfectly substitutable for domestically and locally produced goods. The substitution elasticities and other technical descriptions are provided in the Appendix and an up-to-date introduction is available at http://scholar.pku.edu.cn/hanchengdai/imedcge. This