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Achieving Copenhagen target through carbon emission trading: Economic impacts assessment in Guangdong Province of China

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ABSTRACT

This study analyzed the economic impacts of carbon ETS (emission trading scheme) policy among four energy intensive sectors in Guangdong province with a two-region dynamic CGE model. Five cases are considered to achieve Copenhagen target towards 2020 in Guangdong, including a reference case, two cases under different carbon emission constraints without carbon ETS, and two cases with ETS. The simulation results show that carbon price and economic impacts are closely related to both emission constraints and ETS. In the scenario that overshoots Copenhagen target and does not consider ETS, carbon mitigation cost of refinery and iron & steel sectors would be relatively higher whereas that of power and cement sectors would be lower, and the GDP (gross domestic production) loss would be 1.4%. On the contrary, with ETS implemented, the trading carbon price would be 38 USD (US Dollar)/ton-CO_2, creating a carbon market of around 1 billion USD. Furthermore, ETS could significantly reduce the mitigation cost for the whole economy. The GDP of Guangdong province would recover by 2.6 billion USD. In addition, the economic output and employment of sectors with would be affected compared to the scenario without ETS.

1. Introduction

In order to mitigate global warming and meet the long-term goal of preventing a global temperature rise of more than 2 °C, it is necessary to reduce global GHG (greenhouse gas) emissions by 50% by 2050 compared with 1990 [12]. China is the largest CO_2(carbon dioxide) emitter in the world today, accounting for nearly 9 Gt in 2010 [21]. At the 15th Conference of the Parties (COP 15) to the UNFCCC (United Nations Framework Convention on Climate Change) in Copenhagen, Denmark, China made a pledge to reduce its CO_2 emission intensity per unit GDP (gross domestic production) by 40%–45% by 2020 compared to 2005 level. To achieve the Copenhagen commitment, China set a target of reducing its CO_2 emissions intensity by 17% by 2015 compared to 2010 levels in its 12th FYP (Five-Year-Plan) which includes a series of economic development initiatives by mapping strategies for economic development, setting growth targets and launching reforms. To ensure implementation of the CO_2 intensity target, the State Council announced in December 2012 a document (State Council Document No.41) which introduced a TRS (Target Responsibility System) and provided concrete measures to be implemented until 2015. Under the TRS, national targets are discomposed and allotted to local governments as mandatory targets with measures to reward or punish [30]. As one of the economic engines and populous provinces in China, Guangdong Province, well known as Pearl River Delta Economic Zone, contributes 11.6% of national GDP and has an economy larger than Turkey, Poland or Saudi Arabia. In 2007 it produced over 10% of China's textile, paper, chemicals, non-metal and metal products, and machinery, and over 35% of China's electronic equipment (Table 1); as a result, it consumed 5% of China's coal, 6.5% of natural gas, 10% of electricity, and 15% of refined oil. Therefore, the energy and climate policies in Guangdong would have non-negligible implications for China and the world.

Recognizing the limited efficacy of top-down type administrative measures in achieving energy intensity target set up in 11th FYP, China is now looking at market based instruments such as environmental/carbon taxation and emission trading to reduce the energy- and carbon intensity. ETS (emissions trading scheme) as originally described by Ref. [7] is seen as a market-based instrument to efficiently reduce greenhouse gas emissions. Participants, which could be an entire industry, country, or a set of countries, are

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Table 1
Selected indicators of Guangdong province in 2007.

	Value	Share in China
Population (Million persons)	94.49	7.2%
Energy (Peta Jour (PJ)) and emissions (Million ton)		
Coal	2670.1	5.0%
Petrol oil	1980.2	14.9%
Gas	178.2	6.5%
Electricity (Tera Watt hour (TWh))	3394.1	10.4%
CO_2	414.7	7.02%
Economic indicators (billion 2007 US Dollar (USD))		
GDP	405.3	11.6%
Per capita GDP	4289	1.61
Textile	72.2	12.3%
Paper and pulp	18.9	16.2%
Chemicals	96.6	12.0%
Non-metal products	32.8	12.0%
Metal products	47.3	20.1%
Machinery	175.4	13.4%
Electronic equipment	207.2	37.8%
Other manufacturing	138.5	10.7%

Source: energy data from Ref. [18]; economic data from Ref. [20]; population from Ref. [19] and the authors calculation.

allocated a certain quantity of emission allowances within a specified period. If participants want to emit more/fewer emissions than covered by their allowances, they can either buy or sell allowances. As market theory proposes, the participants will adjust their buying and selling behavior according to their marginal abatement costs. If marginal abatement costs are higher than the price of allowances, participants will buy additional allowances; if they are lower, it is beneficial to sell allowances or to buy fewer [2,11].

In November 2011, the NDRC (National Development and Reform Commission) officially approved the initiation of carbon trading pilots in seven provinces and cities. After Shenzhen, Beijing and Shanghai, Guangdong launched China's fourth carbon ETS in 2013. The Guangdong ETS pilot covers 202 companies across 4 energy intensive industrial sectors (and will increase to 9 in 2014). It represents over 56% of its carbon emissions and is the world's 5th largest carbon market. The Guangdong pilot differs from others in that it is the only scheme with an auction element (3% of total emissions). The first permits of 3 million ton-CO_2 was auctioned at 10 USD/ton-CO_2 and was over-subscribed. Market-based policy instrument are proposed with electricity, cement, iron and steel, and refinery sectors being the ETS participating sectors. The experience from Guangdong Province will be quite relevant for NDRC to develop a national ETS scheme.

CGE models are widely used in analyzing impacts of policies such as taxes, subsidies, quotas or transfer instruments. They stem from the general equilibrium theory of Walras implying that supply and demand are equalized across all of the interconnected markets in the economy. They combine the abstract general equilibrium structure formalized by Arrow and Debreu with realistic economic data to solve numerically for the levels of supply, demand and price that support equilibrium across a specified set of markets [23].

Assessing energy and climate policy with CGE models has attracted increasingly interest in China, such as renewable energy deployment [31], energy investment and energy efficiency [9,15], national absolute and intensity-based carbon limits [5,27], carbon taxes and environment taxes [14,22]. Especially, several studies assessed inter-provincial emission trading or regional carbon intensity targets using multi-region CGE model [3,26,29]. However, most existing multi-region CGE models are static, and ETS is among regions.

Given this context, in this study, we aim to assess the economic impacts of carbon ETS between four energy intensive sectors in Guangdong Province based on a dynamic two-region CGE model. This study is policy relevant in several aspects: first, Guangdong is one of the pilot provinces selected by NDRC to implement carbon emission trade policy, so the experiences would be important for designing national ETS. Second, Guangdong has the highest GDP in China, so the impacts of any climate policy on its economy must be carefully assessed before implementation. Third, the emission caps specified in the scenario of this study are actual policy in Guangdong province, thus the numerical simulation findings are rather policy relevant.

The remaining part of this paper is organized as follows: Section 2 introduces the CGE model, data and scenario. Section 3 shows the results with respect to carbon emissions, carbon intensity, sectoral carbon abatement cost, emission trading, and impacts of ETS on sectoral output, employment and GDP. Section 4 discusses the results, and the paper concludes with final remarks in Section 5.

2. Methodology

2.1. The CGE model

2.1.1. The static model

This study uses a dynamic CGE model jointly developed by NIES (National Institute for Environmental Studies) Japan and GIEC (Guangzhou Institute of Energy Conversion) China. The model is a two-region recursive dynamic CGE model that includes Guangdong (GD) Province and the ROC (Rest of China). The technical description of the static module is provided in the Appendix.

The major model features are similar to the one-region dynamic version [6]. It includes a production block, a market block with domestic and international transactions, as well as government and household income and expenditure blocks. The model is comprised of 33 sectors (Table A 1) which are classified into basic and energy transformation sectors, and 7 power generation technologies (Table A 2). Activity output of each sector follows a nested CES (constant elasticity of substitution) production function. Inputs are categorized into material commodities, energy commodities, land, labor, capital and resource.

The major difference from the one-region model lies in the market block. On the export side, output produced in each region is converted through a CET (constant-elasticity-of-transformation) function into goods destined for own regional, other regional, and international markets. On the import side, Armington assumption [1] is adopted, whereby goods produced from other provinces and abroad are imperfectly substitutable for domestically produced goods. Labor is assumed to be fully mobile across industries within a region but immobile across regions, whereas vintage capital is assumed to be immobile across either regions or industries.

2.1.2. The dynamic process

The model is solved at one-year time step towards 2030 in a recursive dynamic manner, in which the selected parameters, including capital stock, labor force, land, natural resource, EEI (energy efficiency improvement), TFP (total factor productivity), land productivity, and extraction cost of fossil fuels, are updated based on the modeling of inter-temporal behavior and results of previous periods.

2.1.3. Carbon emission trade module

For the purpose of this study carbon emission trade module is added in which cap-and-trade policy could be implemented at sectoral level. As Fig. 1 illustrates, $C1$ and $C2$ are the demand curves of carbon emission rights of sector 1 and 2, when emission allowances, Q_1 and Q_2, are allocated to each sector without carbon trading, the CGE model will find equilibrium points, A and B, with carbon shadow prices of P_1 and P_2 ($P_1 < P_2$) for sector 1 and 2, respectively. By contrast, when free carbon trading is allowed, an identical carbon trading market will be formed. Sector 1 tends to purchase ΔQ_1 unit of carbon emission rights from the market while