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Assessing the Contribution of Carbon Emissions Trading in China to Carbon Intensity Reduction

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Abstract
This paper assesses the impacts of emissions trading between Jiangxi Province and the Rest of China on the carbon prices, total cost of carbon reduction and GDP loss using a two-region provincial Computable General Equilibrium model developed for China. The results reveal that without emissions trading, the carbon prices in 2020 would be 46.8 US$ in Jiangxi Province and 23.2 US$ in the rest of China, leading to GDP loss of 1.07% and 0.79% respectively. However, if emissions trading is allowed between provinces, Jiangxi Province needs to import CO_2 emissions allowance from the rest of China. In 2013, the trading amount is 14.30 million ton or 7.84% of total CO_2 emissions of Jiangxi Province. In 2020, the trading amount triples as compared to 2013, to a level of 44.85 million ton, accounting for 19.37% of Jiangxi's total emissions. The results also reveal that the total costs of Jiangxi Province and the whole China would fall due to emissions trading, which is consistent with the theoretical implications. It is found that in the case of emissions trading, the GDP loss in 2020 would be lower for Jiangxi Province, at 0.36% instead of 1.07%.

Key words: Domestic carbon emissions trading; 2-regional CGE model; China

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INTRODUCTION

Emissions trading as originally described by Dales[1] 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 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 behaviour 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, 3].

One advantage of emissions trading is that reductions are achieved where one ton of carbon dioxide can be avoided most cost-effectively. Therefore, emissions trading minimizes the total cost to the economy of all avoidance measures. Another potential advantage is that the resulting carbon price would improve long-term predictability, a crucial factor for businesses to make efficient investment decisions. In the long run, emissions trading will lead to the deployment of more efficient technologies and to an increased availability of renewable energy[4]. However, these advantages are based on the assumption of a perfect market, complete information and rational behavior by all market players. This assumption does not hold in practice and that leads to serious market failures[3].

So far, there are several emissions trading schemes. On a global level, emissions trading between governments has been established as one of three flexible mechanisms in the framework of the Kyoto Protocol. On the national level, many industrialized countries have either introduced or are considering company-based emissions trading systems, such as the Regional Greenhouse Gas Initiative (RGGI) in the north-east of the US, in California or the various proposals for a US cap-and-trade scheme in the US Senate or in Australia 11[4]. On the supranational level, the European Union established today's largest company-based greenhouse gas emissions trading scheme which is operating since 2005. It encompasses about 11,500 installations from all its Member States, responsible for around a third of the EU's greenhouse gas emissions, and roughly 45% of the EU's CO_2 emissions[5].

In the past decades, China has transformed from an agriculture-based to an industry-based country. At the same time, its growth has been driven by a large, growing trade surplus and rising investment in energy-intensive sectors rather than domestic consumption, which partially led to China's growing demand for energy and rocketing CO_2 emissions in the early 2000s[6]. After overtaking United States as the largest carbon dioxide (CO_2) emission country in 2007, China again surpassed United States and became the world's top energy consumer in 2010[7]. For this reason China is faced with mounting pressures to take on emissions commitments and energy conservation. As a reaction to the pressure and in order to resolve the conflicts between energy supply and demand, as well as to address the related environmental problems, the Chinese government has made significant efforts to formulate energy-saving and climate policies. In 2009, China committed to lower its CO_2 emissions per unit of gross domestic product (GDP) by 40-45% by 2020 compared to the 2005 level, and increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020[8]. In order to fulfill the commitment, China has made stepwise five-year targets to cut the energy intensity by 20% and 16% in its Eleventh (2006-2010) and Twelfth (2011-2015) Five-Year Plans for National Economic and Social Development[9,10], respectively. By 2010, China almost achieved the first target with the actual energy intensity and carbon intensity in terms of GDP decreasing by 19.1% and 17%, respectively. Furthermore, China has launched substantive initiatives at both national and provincial levels to promote low carbon development. The National Development and Reform Commission of China (NDRC) has decided to run the first pilots for low carbon development in five provinces and eight cities. The selected provinces and cities are required to carry out actions such as making low-carbon development plan, developing policy to support low-carbon development, accelerating the establishment of industries characterized by low carbon emissions, and proactively advocating low-carbon green lifestyle[11]. More recently, China has decided to establish carbon emissions trading market in China[10].

So far, very few studies deal with China's domestic emissions trading and its impacts on the economy and energy consumption. In this context, this study aims to assess the carbon emissions trading at provincial level using a two-region CGE model developed for China. This model and analysis could be applied to any province given the necessary dataset.

Jiangxi Province is selected as an example. Jiangxi is an inland province located in southeast of China. Its population (39.66 million) and area are 3.35% and 1.74% of whole China, respectively. Jiangxi is a rather poor province when compared to its neighboring provinces. In 2009, its GDP was 765 billion yuan (112.1 billion USD, per capita 2515 USD), accounting for 2.10% of total GDP of China[12].

The emissions target is set in such a way that the carbon intensity of GDP will be reduced by 45% in 2020 compared to 2005. We would like to assess the carbon prices, economic impacts of emissions reduction in the cases of with and without emissions trading, as well as the potential amount of emissions trading and implications for energy consumption.

The rest of the paper is organized as follows. Section 1 introduces the CGE model. Section 2 shows the results with respect to energy intensity and carbon intensity, energy consumption and CO_2 emissions, carbon prices and emissions trading, and GDP change due to carbon constraints and emissions trading. The paper concludes with some final remarks at the end of this paper.

1. METHODOLOGY

Scenario analysis is conducted using a two-region recursive dynamic CGE model extended from the static and dynamic version for China[13, 14]. There are two regions in this model, Jiangxi Province and the Rest of China, which interact with each other through domestic trade. The model includes a production module, final demand modules by government and household, a domestic transaction module and an international transaction module. Various key technologies are considered in the energy intensive sectors, such as non-fossil electricity generation, alternative fuel production (bio-liquid and bio-gas), carbon capture and storage (CCS). The model is solved by GAMS/MPSGE[15].

1.1 Production Sector

There are 41 sectors in this model, seven of which are energy sectors (Table 1). Sectors are classified into basic, land-requiring, resource-requiring, and energy transformation sectors. Activity output of each sector follows a nested constant elasticity of substitution (CES) production function. Inputs are categorized into material commodities, energy commodities, traditional biomass, land, labor, capital and resource. The technologies include power generation technologies and CCS technologies as well as biomass to liquid and biomass to gas technologies. Activity output is determined by the aggregation of fixed coefficients of non-energy and energy intermediate commodities, traditional biomass, and primary factors. The composite of non-energy inputs is in Leontief form. Energy and value added bundle is nested by valued added and energy inputs. Value added bundle is a CES function of primary factors. The composite of energy inputs is a CES aggregation of electricity and fossil fuels. Fossil fuels are further disaggregated into five types. Data for elasticity of substitution in energy bundle were adopted from Li[16] and Wu[17].

Table 1
Sector/Commodity Definition in the Model

Nr.	Basic sectors	Nr.	Basic sectors
1	Textiles and clothing	23	Railway transport
2	Chemicals	24	Road transport
3	Nonmeta llic mineral products	25	Urban public passenger transport services
4	Other nonmeta llic products	26	Water transport
5	lron and steel smelting and pressing	27	Air transport
6	Nonferrous metals	28	Other transport
7	Grain mill products	29	Storage and warehousing
8	Vegetable oil refining		**Energy transformation sectors**
9	Slaughte ring and meat processing	30	Gas production and supply
10	Beverages	31	Petroleum and nuclear fuel processing
11	Other food manufacturing	32	Coking
12	Paper and paper products	33	Electricity
13	Metal products		**Land requiring sectors**
14	Transport equipment	34	Agriculture
15	Machinery	35	Forestry
16	Electronic equipment	36	Animal Husbandry (livestock)
17	Other manufacturing		**Resource requiring sectors**
18	Water production and supply	37	Mineral mining
19	Construction	38	Other agriculture
20	Scientific research and education	39	Coal mining
21	Health, social security and welfare	40	Extraction of petr oleum
22	Services	41	Natural gas

1.2 Household and Government Sectors

Household and government are final consumers. The representative household receives income from the rental of primary factors and lump-sum transfer from the government. The income is used for either investment or consumption. Household maximizes its utility by choosing the levels of consumption of commodities, subject to the constraints of its income and commodity prices.

The government collects taxes, including carbon tax, and the revenue from carbon tax is recycled to the representative agent as a lump-sum transfer. Based on a Cobb-Douglas demand function[18], the government also spends its revenue on public services which are provided to the whole society and on goods and services which are provided to the households free of charge or at low prices[19].

1.3 Domestic and International Transaction

The produced goods and commodities are distributed to international and domestic markets first. Like most other country CGE models, this model assumes a small open economy, meaning that the economy is small enough for its policies not to alter world prices or incomes. Future international prices are assumed to be at a constant level for non-energy commodities and increase by 3% yearly for energy commodities from 2005 onwards. Produced goods are distributed to domestic and international markets with an elasticity of transformation of 2. Within the domestic markets, the products are sold either in the local market or rest of China with the elasticity of transformation being 3. The Armington assumption is used to distinguish identical local goods, goods from other provinces, and imported goods. The elasticity of substitution between imported and domestic goods is adopted from Li[16] (Appendix A1), while that between local market and the other provinces is twice as high as import/domestic value.

1.4 Base Year Data

The dataset used in this model includes an input-output table[19, 20], energy balance table[21], GHG emission factors, and data on characteristics of electricity generation technologies. All the datasets are converted to the base year of 2005. Detailed description of these datasets could be found in Dai *et al*.[13].

1.5 Dynamic Process and Scenario

As a recursive dynamic CGE model in which the agents' behavior is based on adaptive expectations rather than forward-looking expectations, the model is solved one period at a time[22], and the selected parameters, including capital stock, labor force, land, energy efficiency, total factor productivity, labor productivity, land productivity and the extraction cost of fossil fuels, are updated based on the modeling of inter-temporal behavior and results from previous periods.

This study analyzes three scenarios, including the Reference Scenario (RS), NoTRADE scenario and TRADE scenario (Table 2).

All scenarios share some common assumptions in population, investment, AEEI, and total factor productivity (TFP), and other parameters. AEEI is assumed separately for liquid, solid and gas fuels. AEEI of gas fuel is -1%, reflecting the fact that fuel switch to natural gas will take place naturally in future. Non-fossil fuel use, including nuclear power, hydro power, solar power, wind power and biomass, follows the assumption in the report released by Energy Research Institute[23]. We also assume the economy will decouple from the energy intensive products such as cement, iron and steel, chemistry products and paper, reflecting the dematerialization trend in the future[24-26].

The scenarios differ from each other in the assumption on emissions trading and carbon emissions cap. In RS, no carbon emissions constraint is imposed on China. In the other two scenarios, carbon intensity of GDP will reduce by 45% in 2020 compared to 2005 in both Jiangxi Province and the rest of China. However, the NoTRADE scenario doesn't allow emissions trading, while in the scenario TRADE free emissions trading between the two regions is allowed.

Table 2
Key Assumptions in Scenarios

Common assumptions	**Scenario** 2005-2010	2010-15	2015-20
GDP growth rate	9.5%/year	8.8%/year	7.2%/year
TFP improvement	5%/year	4%/year	3.5%/year
Population	0.63%/year	0.61%/year	0.50%/year
	UN2008 medium projection;		
Total investment increase	ln line with the GDP growth;		
Autonomous energy efficiency improvement(AEEI)	3% for solid fuel 2% for liquid fuel 2% for electricity,and-1% for gas fuel;		
Different assumptions	**RS**	**NoTRADE**	**TRADE**
Non-fossil energy	Refer to 23		
Carbon Cap	No cap in RS.Carbon cap from 2013 in other two scenarios. Carbon intensity reduces by 45% in 2020 compared to 2005.		
Emissions trading	Without emissions trading in NoTRADE scenario, with emisisons trading in TRADE scenario		

Data source[23, 27]

2. RESULT

In this part we show the results of energy and CO_2 emissions, energy and carbon intensity, carbon prices and emissions trading, and GDP change due to carbon constraints and emissions trading.

2.1 Energy and Carbon Intensity

In 2005, carbon and energy intensities of Jiangxi Province are lower than the rest of China (Figure 1), reflecting the fact that Jiangxi Province is relatively underdeveloped where the agriculture and light industry dominate its economy.

In the reference scenario, the intensities in both regions fall steadily from 2005 to 2020 due to energy price increase and technology improvements such as energy efficiency improvement and factor productivity improvement. However, even though the energy intensities of both regions reduce at same speed, by about 29% in 2020 compared with 2005, the speed of carbon intensity improvement is different; the carbon intensity of the Rest of China falls by 29% while that of Jiangxi Province falls by only 21%. The reason is that relatively more renewable energy is used in the Rest of China throughout 2020, but the energy consumption increase of Jiangxi Province derives mainly from carbon intensive coal and oil.

In the carbon constraint scenarios, without emission trading, carbon intensities of Jiangxi Province and the Rest of China reduce by 44.3% and 44.6%, respectively. China's Copenhagen climate commitment in 2009 is achieved. However, with emissions trading, the actual carbon intensity of Jiangxi Province reduces only by 34.0%, which is lower than the previous reduction of 44.3%. On the other hand, the carbon intensity of the Rest of China reduces by 44.8%, which is slightly higher than without emission trading scenario.

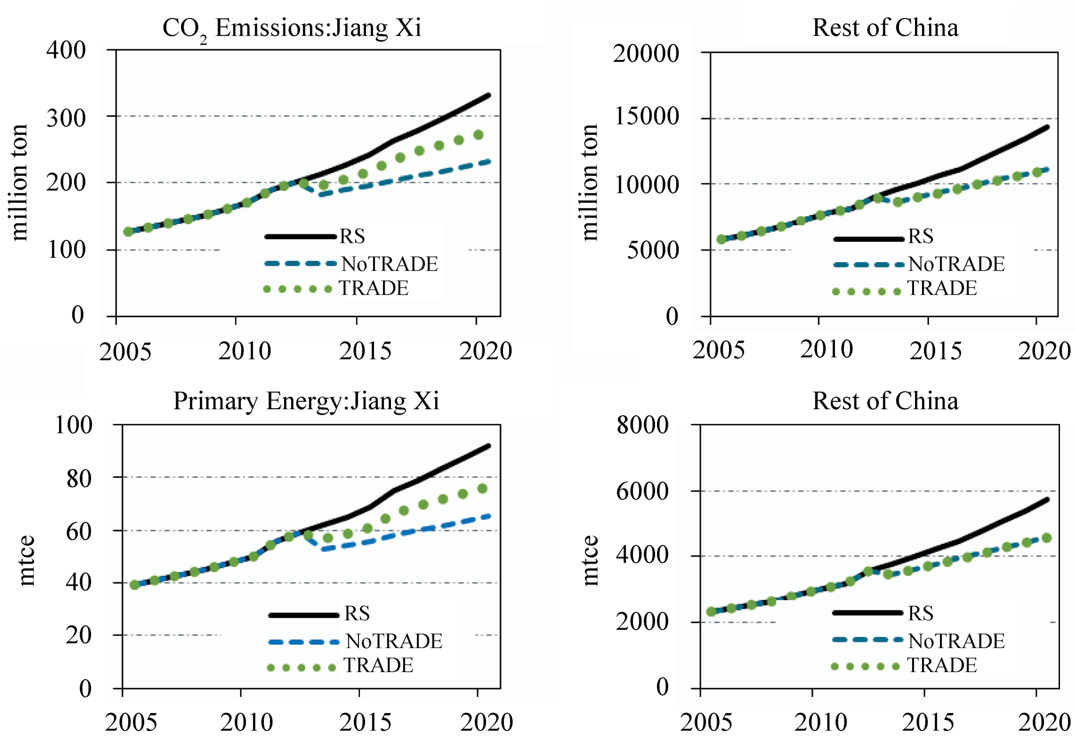

Figure 1
Carbon (Upper Two) and Energy (Lower Two) Intensity Trajectory

2.2 CO_2 Emissions and Energy Consumption

In contrast to intensity reduction, CO_2 emissions and energy consumption increase in all scenarios and regions due to the main driving force of tremendous per capita GDP increase (Figure 2). If China achieves the Copenhagen carbon intensity reduction target, the total emissions and energy consumption would be lower than in the reference scenario.

With emissions trading, the actual emissions of Jiangxi Province are higher than in without emissions trading's case, which leads to higher actual carbon and energy intensities as mentioned in the previous section. This implies that Jiangxi Province needs to import carbon emissions allowance from the Rest of China. The reason will be explained in the next section by shedding light on carbon price difference between the two regions.

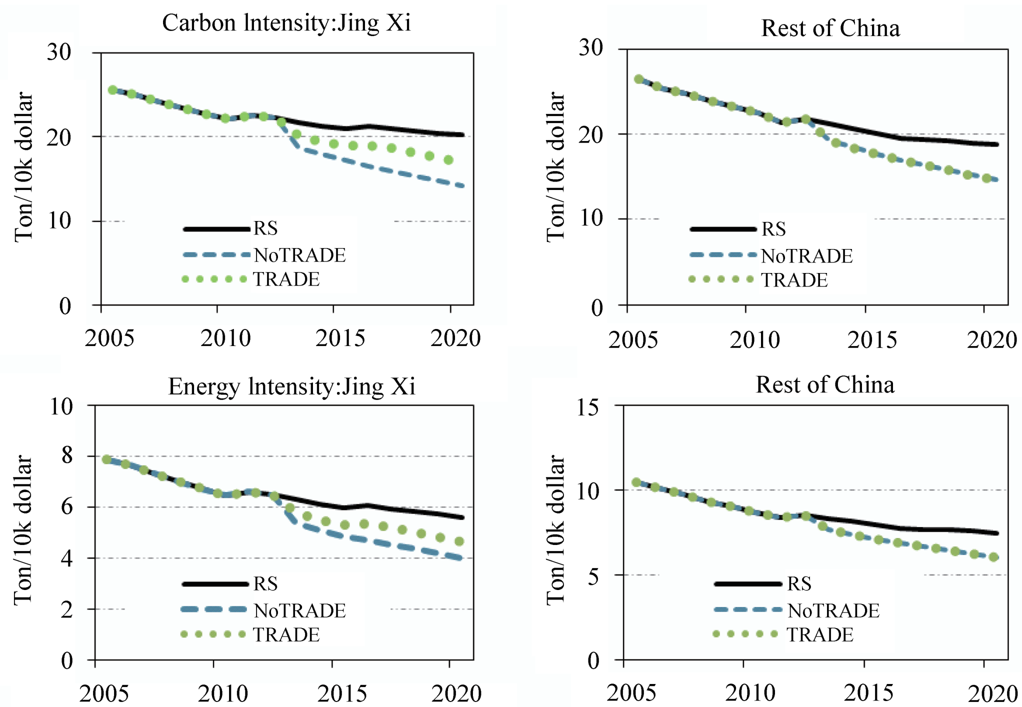

Figure 2
Total CO_2 Emissions (Upper Two) and Primary Energy Supply (Lower Two)

2.3 Carbon Price and Carbon Emissions Trading

The previous results imply that Jiangxi Province needs to import carbon emissions allowance from the Rest of China. In fact, as showed in Figure 3, the emissions trading starts from 2013, immediately after carbon constraints are imposed. The trading amount is 14.3 million ton of CO_2 in 2013 and increases drastically to 44.9 million ton in 2020, accounting for 7.8% and 19.4% of total emissions of Jiangxi Province in those years, respectively.

The emissions trading takes place because of the carbon price difference between the two regions. As shown in Figure 3, without emissions trading, the carbon price of Jiangxi Province is always around two times as high as the Rest of China during 2013 to 2020, which results in the necessity of import of carbon allowance for Jiangxi Province. When emissions could be traded freely, the carbon prices of both regions become equal, and the carbon price of Jiangxi Province falls by around 50% while that of the Rest of China increase slightly by 1-2%. Carbon reductions are achieved where one ton of carbon dioxide can be avoided most cost-effectively, which is consistent with the economic theory.

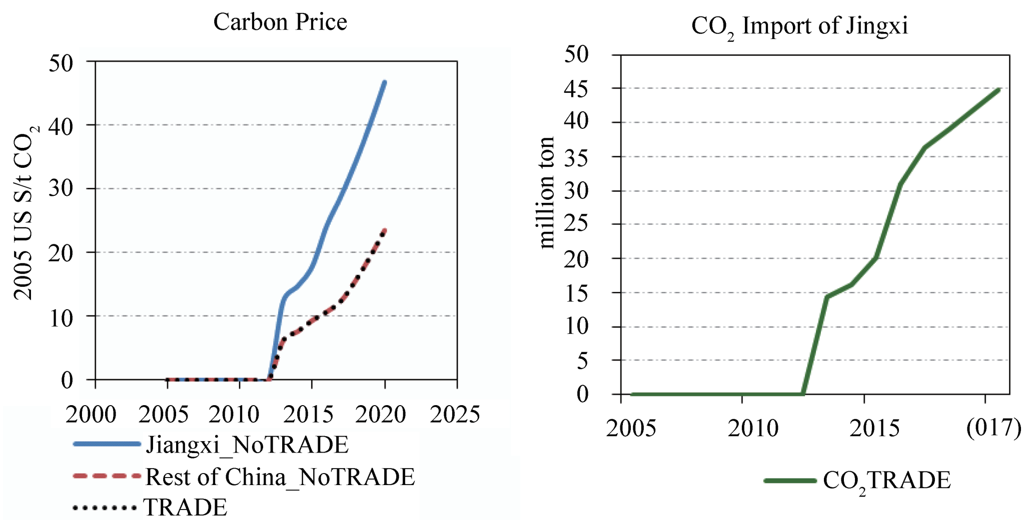

Figure 3
Carbon Prices and Emissions Trade

2.4 Economic Impacts

After analyzing the influences of emissions trading on carbon prices and emission reduction costs, we now present the results of economic impacts. As illustrated in Figure 4, without emissions trading the GDP loss of Jiangxi Province in 2020 is 1.07%, whereas with emissions trading the GDP loss becomes much less at 0.36% as a result of decrease in carbon reduction cost. The economic impacts of emissions trading on the Rest of China are little since the change in carbon price is insignificant.

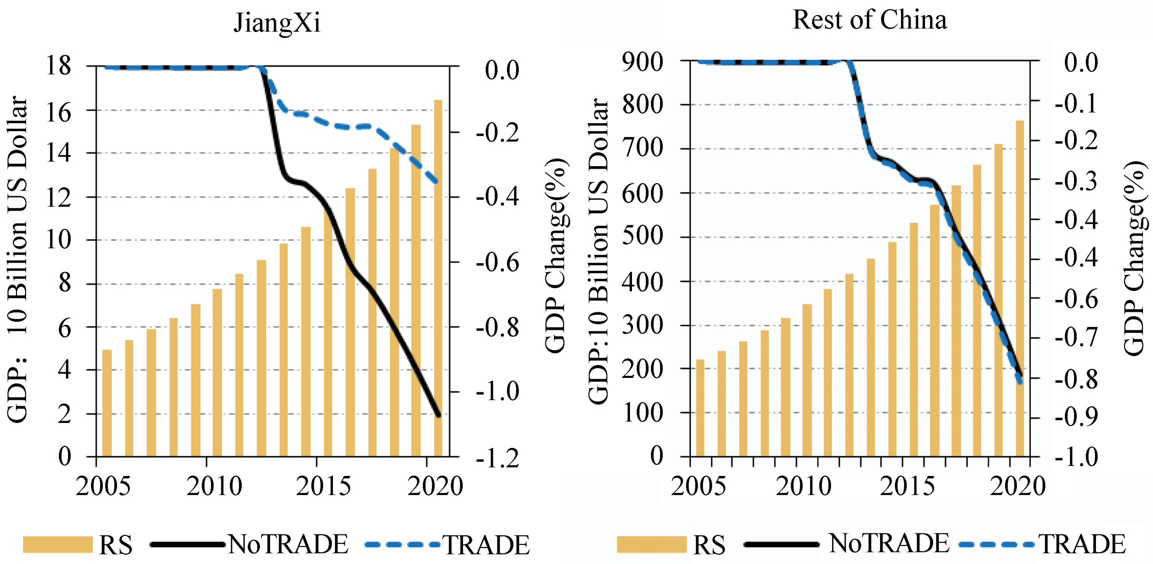

Figure 4
GDP in the Reference Scenario (Pillar) and GDP Change (Line) in the Other Scenarios Compared to the Reference Scenario

DISCUSSION AND CONCLUSION

In this paper we have analyzed the emissions trading at provincial level in China using a two-region recursive dynamic CGE model. To the best of our knowledge, this is the first attempt to assess China's domestic emissions trading and its impacts on the carbon price, carbon reduction cost, and the economy. In principle, this two-region model could be applied to any other province in China and other countries given the necessary dataset.

It is clear from the results that since Jiangxi province has an underdeveloped economy with relatively little heavy industry, its energy intensity is 25% lower than in the Rest of China in 2005. However, despite the lower energy intensity the carbon intensity is almost the same as in the rest of China. This is because the share of carbon intensive coal and oil being 95% in 2005, Jiangxi Province's energy composition is more carbon intensive that the Rest of China (fossil energy share being 93% in the latter). Even without carbon constraints, the carbon intensity and energy intensity would reduce in both regions due to energy price increase and technology improvement, but the naturally occurring reductions are not sufficient to achieve China's Copenhagen Commitment of 45% carbon intensity reduction. Additional mitigation policy such as carbon tax must be introduced.

If carbon constraints are imposed on the economy of Jiangxi Province and the Rest of China without emissions trading, the carbon prices in 2020 would be 46.8 US$ and 23.2 US$ in the two regions, respectively. The corresponding reduction costs in the two regions are 1.08 and 25.8 billion US$, leading to GDP loss of 1.07% for Jiangxi Province and 0.79% for the rest of China.

However, the picture would be different if the emissions trading scheme is introduced. Since the carbon prices in the Rest of China are merely half of Jiangxi Province in the whole period of 2013 to 2020, it is cost effective to reduce CO_2 emissions in the Rest of China. Therefore, it is beneficial for Jiangxi Province to import CO_2 emissions allowance from the Rest of China. In 2013, the trading amount is 14.30 million ton CO_2 or 7.84% of total CO_2 emissions of Jiangxi Province. With time Jiangxi Province depends more and more on emissions import from the Rest of China. In 2020, for example, the trading amount triples as compared to 2013, to 44.85 million ton, accounting for 19.37% of Jiangxi's total emissions. The results also reveal that the GDP loss would be lower for Jiangxi Province in the case of emissions trading, at 0.36% instead of 1.07%.

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APPENDIX

Table A1
Elasticity of Substitution Between Domestic and Imported Commodities[16]

Commodity	Substitution elasticities	Commodity	Substitution elasticities
Agriculture	2.94	Machinery	4.4
Forest	2.5	Electronic	4.4
Livestock	0.9	Other manufacturing	3.75
Other agriculture	1.25	Water supply	2.8
Mineral mining	5	Construction	1.9
Textile	3.75	Serivices	1.9
Chemistry	3.3	Transportation	1.9
Non-metal products	2.9	Coal mining	1.25
Metal products	3.58	Oil and gas mining	3.05
Food production	2.96	Refin ed oil	2.1
Paper production	2.95	Town gas	2.8
Transport	2.8	Electricity	2.8