China's inter-regional spillover of carbon emissions and domestic supply chains

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journal or publication title	IDE Discussion Paper
volume	367
year	2012-09-01
URL	http://hdl.handle.net/2344/1254

INSTITUTE OF DEVELOPING ECONOMIES

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IDE DISCUSSION PAPER No. 367

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September, 2012

Abstract

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Keywords: Trade in CO2 emissions, CO2 emissions in trade, input–output, supply chains, embodied CO2 emissions, Chinese regional economies

JEL classification: C6, F4, O18, F18, Q21

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In this study, we apply the inter-regional input–output model to explain the relationship between China's inter-regional spillover of CO_2 emissions and domestic supply chains for 2002 and 2007. Based on this model, we propose alternative indicators such as the trade in CO_2 emissions, CO_2 emissions in trade, regional trade balances, and comparative advantage of CO_2 emissions. The empirical results not only reveal the nature and significance of inter-regional environmental spillover within China's domestic regions but also demonstrate how CO_2 emissions are created and distributed across regions via domestic production networks. The main finding shows that a region's CO_2 emissions depend on not only its intra-regional production technique, energy use efficiency but also its position and participation degree in domestic and global supply chains.

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1 Introduction

China has exhibited a high rate of economic growth during the last three decades. Its economic scale in real terms expanded almost 2.6-fold from 1987 to 1997 and jumped again from 1997 to 2007[1]. In 2010, China's nominal GDP surpassed that of Japan, becoming the second largest economy in the world. The most important factors that enabled China to achieve such high economic growth are generally considered to be its domestic market-oriented economic reforms, ongoing urbanization, industrialization, domestic regional integration, and active participation in global supply chains. The interactions between these forces provide a powerful engine to support the so-called "China Miracle."

However, China has also paid a great environmental cost during the period of its rapid economic growth, including pollution (air, water, ground, and noise) causing health problems and decreasing people's quality of life as well as CO_2 emissions, which are considered the primary source of greenhouse gases (see Xue et al., 2012). At present, China is one of the countries with the largest area exposed to acid rain. In addition, China's emissions of organic wastewater, sulfur dioxide, and various greenhouse gases are the highest in the world. China even leads in CO_2 emission intensity (CO_2 emissions per GDP at constant prices) with a rate more than 6 times larger than that of the OECD countries in 2008[2]. Therefore, China has been referred to as the "Black Cat" rather than "White Cat" (see Hu, 2011).

On the other hand, it is not well known that the Chinese government has made great efforts toward energy saving and emission reduction in response to global climate change. Since 1998, China has enacted a variety of laws and regulations to foster a low carbon economy. During the period of the 11th Five Year Plan (2006–2010), China's energy-use intensity witnessed a decline by 19.1%, fulfilling the Plan's basic requirement. As Garnaut (2008) noted, China has put in considerable efforts in dealing with climate change, but little is known because China did not integrate itself into the international system. In 2009, China officially promised the international community at the Copenhagen Conference that it would reduce its carbon emissions per GDP by 40–45% by the end of 2020, relative to the 2005 level (see Su, 2010). To achieve this goal, governments at different levels, diverse sectors, major industries, and companies must adopt a series of relevant policies and stringent regulations.

To analyze China's environmental problems, low carbon and sustainable economic development, as well as its green growth strategy, a number of studies have been conducted using different approaches. Examples include the following studies: approaches from low-carbon related economic growth and development theories (Arayama and Miyanaga, 1996; Liu and Diamond, 2005; Zhang, 2009; Xue and Zhu, 2012); low-carbon econometrical models (China AIM Project Team, 1996; Jiang et al., 2000); viewpoints of low-carbon international economics (Garnaut, 2008; McKibbin and Wilcoxen, 2008); approaches of low-carbon international trade theory (Ahmad and Wyckoff, 2003; Wang and Watson,

[1] Based on the IMF statistics, China's GDP at constant price (1990 base) are 1.609 trillion yuan for 1987, 4.149 trillion yuan for 1997, and 10.691 trillion yuan for 2007.
[2] Based on the OECD/IEA data (CO2 emissions from fuel combustion highlights 2010).

2007; Pan, 2008; Nakano et al., 2009) as well as the perspectives from tariff theory, domestic finance and taxation, low-carbon business models, and so on[3]. However, most of the above models treat China as a whole rather than focusing on its domestic regions. Because of the great variation in economic size, industrial structure, energy-use efficiency, and overseas dependency across regions within China, there is a need for more regional level perspectives to improve the understanding of the detailed creation and distribution of CO_2 emissions. In addition, regional level analyses provide important information and reference points for local governments, who are the actual executors of the central government's environmental policies.

Since the recent improvement of China's provincial environment related statistics, regional level studies on CO_2 emissions have been available. For example, Liang et al. (2007) employ the multi-regional Input–Output (I/O) model to measure China's regional energy requirements and CO_2 emissions for 2010 and 2020. Their empirical results demonstrate that by 2020, improvement in energy end-use efficiency for each region could generate intra-regional energy savings; population growth in one region will not only significantly affect that region's energy requirements but also increase other regions' energy-use. Feng et al. (2009) study how population, affluence, and emission intensity have contributed to the growth of CO_2 emissions in five regions of China. Their results demonstrate that China must ensure that people's lifestyles are changing to more sustainable ways of living. Using the CO_2 emissions related index decomposition technique, Liu et al. (2010) analyze China's carbon emission changes during 1997–2007 for 30 domestic provinces. They identify the most important regions that cause higher CO_2 emissions from end-use energy consumption and emphasize that the decline in energy intensity has the greatest impact on CO_2 emissions. Meng et al. (2011) analyze the characteristics of China's regional CO_2 emissions, the effects of economic growth and energy intensity using panel data from 1997 to 2009. Wang and Shi (2012) use the I/O-based carbon footprint model to analyze China's provincial carbon footprint and interprovincial transfer.

Most studies undertaken at the regional level of China focus on measuring energy and CO_2 emission intensities, influencing factors in CO_2 emissions change, and the embodied CO_2 emission in trade. Our study differs in the way in which we focus on clarifying the relationship between China's inter-regional spillover of CO_2 emissions and domestic supply chains. The inter-regional spillover of CO_2 emissions and its evolution depend on a combination of reasons or factors. These factors include not only regional economic scales, regional industry structure, scales of energy-use and CO_2 emissions, and efficiency of energy-use, but also a region's position and participation level in domestic and global supply chains. To explain the CO_2 emissions spillover from the perspective of supply chains or inter-regional production networks, we apply both the traditional I/O-based measure, "CO2 emissions in trade" (CEiT), and the newly developed measure, "trade in CO2 emissions" (TiCE) to China's inter-regional frameworks (eight regions) for 2002 and 2007. The CEiT indictor measures embodied CO2 emissions in trade (international trade or inter-regional trade in goods and services), and the TiCE indicator measures a region's CO_2

[3] For the comprehensive introduction on China-related low-carbon analyses, one can refer to Xue (2012).

emissions caused by other regions' final demand. The TiCE indicator follows the recently proposed concept of "Trade in Value-Added" (TiVA) (Johnson and Noguera, 2011). Meng et al. (2012) apply the TiVA concept to Chinese regional economies to analyze China's domestic value chains. This indicator can avoid double counting in measuring bilateral trade balance. In this study, we investigate both TiCE and TiVA indicators for China's eight regions to clarify the relationship between inter-regional CO_2 emissions spillover and domestic supply (value) chains. We also propose new indictors based on the concepts of CEiT and TiCE, such as embodied CO_2 emissions in the other regions' export, the trade balance of regional CO_2 emissions, and the revealed comparative advantage (RCA) of CO_2 emissions.

The rest of this study is organized as follows. Section 2 explains how we use the I/O model to measure the inter-regional spillover of CO_2 emissions. Section 3 gives a brief explanation of the database used and presents the results of CEiT and TiCE at detailed regional and sectoral levels. Finally, we discuss the relationship between China's inter-regional spillover of CO_2 emissions and domestic supply chains as well as global supply chains in which China's domestic regions are involved. Section 4 presents concluding remarks.

2 Measuring Inter-regional Spillover of CO_2 Emissions

In this section, we propose some alternative I/O-based indicators to measure the inter-regional CO_2 emissions spillover effect. These indicators include CO_2 emissions in trade, domestic trade in CO_2 emissions, CO_2 emission based regional RCA, and the regional export based spillover effect of CO_2 emissions. Most indicators proposed in this section can be traced back to the I/O-based measurement of domestic supply chains in the existing literature (see Meng et al., 2012).

2.1 Regional CO_2 emissions in trade (CEiT)

To investigate the degree of CO_2 emissions embodied in a region's export (foreign trade with the rest of the world) and outflow (domestic trade with the rest of the nation), we first expand the widely converted measure of international embodied CO_2 emissions proposed by Wyckoff and Roop (1994) into a domestic version. The regional I/O-based CEiT can be written as follows.

CO_2 emissions embodied in the exports of region r: $\mathbf{c^r} \cdot (\mathbf{I} - \mathbf{A^r})^{-1} \cdot \mathbf{ex^r}$, and (1)

CO_2 emissions embodied in the outflow of region r: $\mathbf{c^r} \cdot (\mathbf{I} - \mathbf{A^r})^{-1} \cdot \mathbf{ou^r}$, (2)

where $\mathbf{c^r}$ is the $1 \times n$ vector constructed by using region r's CO_2 emissions rate (the share of CO_2 emissions in total input by sector), $\mathbf{A^r}$ is the $n \times n$ intra-regional input coefficient matrix of region r, $\mathbf{I}$ is an $n \times n$ identity matrix, $(\mathbf{I} - \mathbf{A^r})^{-1}$ is the region r's Leontief inverse, and $\mathbf{ex^r}$and $\mathbf{ou^r}$ are the $n \times 1$ column vector of region r's exports and outflow, respectively. The above mentioned indicators represent the CO_2 emissions directly and indirectly caused by regional export and outflow demand by the way of domestic production networks, which can also be explained as the volume of CO_2 emissions embodied in a region's trade.

If a single regional I/O table with separate export data and outflow data is available, the above mentioned indicators can easily be estimated. The indicator shown in equation (2) can yield two additional indicators if the outflow information can be separated into trade in intermediate ($\mathbf{ou}^{\mathbf{r}}_{\mathbf{imd}}$) and final products ($\mathbf{ou}^{\mathbf{r}}_{\mathbf{fd}}$), respectively, as shown below.

CO_2 emissions embodied in the outflow of intermediate products of region r: $\mathbf{c}^{\mathbf{r}} \cdot (\mathbf{I} - \mathbf{A}^{\mathbf{r}})^{-1} \cdot \mathbf{ou}^{\mathbf{r}}_{\mathbf{imd}}$,
CO_2 emissions embodied in the outflow of final products of region r: $\mathbf{c}^{\mathbf{r}} \cdot (\mathbf{I} - \mathbf{A}^{\mathbf{r}})^{-1} \cdot \mathbf{ou}^{\mathbf{r}}_{\mathbf{fd}}$.

The advantages of the above mentioned regional CEiT indicators include the following capabilities: (1) the degree of a region's CO_2 emissions in domestic and global supply chains can be evaluated; (2) the relative position of a region in domestic supply chains, can be taken into account in CO_2 emissions measurements by focusing on intermediate and final products separately.

2.2 Measuring domestic trade in CO_2 emissions (TiCE)

To investigate domestic TiCE and its evolution in detail, we apply the I/O-based concept of domestic TiVA (see Johnson and Noguera, 2011 and Meng et al., 2012) to the measure of inter-regional spillover of CO_2 emissions. Following the concept of TiVA, the domestic TiCE at the regional level can simply be defined as one region's CO_2 emissions caused by another region's final demand or one region's CO_2 emissions "exported"[4] to other regions.

To explain the concept of domestic TiCE, we model a closed economy with only two regions (r and s) and n sectors for each region. Based on the traditional inter-regional I/O model, the total CO_2 emissions can be written in the following form.

$$\mathbf{co_2} = \mathrm{diag}(\mathbf{c}) \cdot \mathbf{L} \cdot \mathbf{fd}, \tag{3}$$

$$\mathbf{co_2} = \begin{pmatrix} \mathbf{co_2}^{\mathrm{r}} \\ \mathbf{co_2}^{\mathrm{s}} \end{pmatrix},\ \mathbf{c} = (\mathbf{c}^{\mathrm{r}}, \mathbf{c}^{\mathrm{s}}),\ \mathbf{L} = \begin{pmatrix} \mathbf{L}^{\mathrm{rr}} & \mathbf{L}^{\mathrm{rs}} \\ \mathbf{L}^{\mathrm{sr}} & \mathbf{L}^{\mathrm{ss}} \end{pmatrix} = \left[\mathbf{I} - \begin{pmatrix} \mathbf{A}^{\mathrm{rr}} & \mathbf{A}^{\mathrm{rs}} \\ \mathbf{A}^{\mathrm{sr}} & \mathbf{A}^{\mathrm{ss}} \end{pmatrix}\right]^{-1},\ \mathbf{fd} = \begin{pmatrix} \mathbf{fd}^{\mathrm{rr}} \\ \mathbf{fd}^{\mathrm{sr}} \end{pmatrix} + \begin{pmatrix} \mathbf{fd}^{\mathrm{rs}} \\ \mathbf{fd}^{\mathrm{ss}} \end{pmatrix}.$$

Here, $\mathbf{co_2}^{\mathrm{r}}$ is the (n × 1) column vector representing region r's CO_2 emissions by sector, $\mathbf{c}^{\mathrm{r}}$ is the (1 × n) row vector of CO_2 emissions rate (the share of CO_2 emissions in total input) by sector for region r, $\mathbf{L}$ is the inter-regional Leontief inverse constructed by the sub-matrix $\mathbf{L}^{\mathrm{rs}}$. $\mathbf{I}$ is a $2n \times 2n$ identity matrix. $\mathbf{A}^{\mathrm{rs}}$ represents the (n × n) matrix of inter-regional input coefficients from region r to region s, and $\mathbf{fd}^{\mathrm{rs}}$ is the (n × 1) column vector representing region s' final demand for goods and services produced in region r. Following the definition of domestic TiVA, we formulate region r's CO_2 emissions exported to region s as follows.

[4]Here, "export" indicates the domestic trade (outflow) to distinguish between the foreign export and the domestic-regional outflow.

$$\mathrm{TiCE}^{rs} = (\mathbf{u},\mathbf{u}) \cdot \mathrm{diag}(\mathbf{c}^{r},\mathbf{0}) \cdot \begin{pmatrix} \mathbf{L}^{rr} & \mathbf{L}^{rs} \\ \mathbf{L}^{sr} & \mathbf{L}^{ss} \end{pmatrix} \cdot \begin{pmatrix} \mathbf{fd}^{rs} \\ \mathbf{fd}^{ss} \end{pmatrix},$$
$$= \mathbf{c}^{r} \cdot \mathbf{L}^{rr} \cdot \mathbf{fd}^{rs} + \mathbf{c}^{r} \cdot \mathbf{L}^{rs} \cdot \mathbf{fd}^{ss},$$
$$= \mathrm{TiCEF}^{rs} + \mathrm{TiCEH}^{rs}. \qquad (4)$$

TiCE^{rs}represents CO_2 emissions of region r caused by the final demands on products in region s produced in both the foreign region ($\mathbf{fd}^{rs}$) and the home region ($\mathbf{fd}^{ss}$). Therefore, this type of TiCE can be considered as a demand-based measurement from the viewpoint of region s (demander). TiCE^{rs}can be further separated into two parts, TiCEF^{rs} and TiCEH^{rs}indicating different types of final demands, specifically, $\mathbf{fd}^{rs}$ and $\mathbf{fd}^{ss}$.

At the product (sector) level, we analyze the forced CO_2 emissions in a specific sector j of region r by a specific final demand for product i in region s as “an individual TiCE linkage” defined as follows:

$$\mathrm{TiCE}_{ij}^{rs} = \mathbf{c}_j^{r}(\mathbf{L}^{rr} \cdot \mathbf{fd}_i^{rs} + \mathbf{L}^{rs} \cdot \mathbf{fd}_i^{ss}). \qquad (5)$$

Based on the above-stated definition, the export of CO_2 emissions of sector j by region r to region s ($\mathrm{TiCE}_{\cdot j}^{rs}$) can be expressed as

$$\mathrm{TiCE}_{\cdot j}^{rs} = \textstyle\sum_i \mathrm{TiCE}_{ij}^{rs}. \qquad (6)$$

In addition, if we use the following measurement (SP), the share of a region’s CO_2 emissions incorporated into its partner region’s exports can be also measured. This approach facilitates the understanding of how a certain region’s CO_2 emissions are affected by other regions’ global supply chains when the region acts as a provider of intermediate products in domestic supply chains.

$$SP^{rs} = (\mathbf{u},\mathbf{u}) \cdot \mathrm{diag}(\mathbf{c}^{r},\mathbf{0}) \cdot \begin{pmatrix} \mathbf{L}^{rr} & \mathbf{L}^{rs} \\ \mathbf{L}^{sr} & \mathbf{L}^{ss} \end{pmatrix} \cdot \begin{pmatrix} \mathbf{0} \\ \mathbf{ex}^{s} \end{pmatrix},$$

2.3 Regional comparative advantage in export of CO_2 emissions

To evaluate a region’s comparative advantage in CO_2 emissions, we apply the concept of domestic TiCE to the measure of regional RCA at the sector level. The concept of RCA is largely based on the theory of Ricardian comparative advantage. The most widely used indicator of RCA is given as follows (BélaBalassa, 1965)

$$\mathrm{RCA}_i^{R} = \frac{\mathrm{EX}_i^{R}/\sum_i \mathrm{EX}_i^{R}}{\sum_R \mathrm{EX}_i^{R}/\sum_R\sum_i \mathrm{EX}_i^{R}}, \qquad (7)$$

where EX_i^{R} represents country r’s exports of product i. This indicator represents a country’s relative advantage or disadvantage in international trade for a certain category of goods or services. Because a region's CO_2 emissions in a specific sector as exported to other regions can be measured by $\mathrm{TiCE}_{\cdot j}^{rs}$, we use this concept to measure a region's comparative advantage in CO_2 emissions as follows

$$\mathrm{RCA}_{\cdot j}^{r} = \frac{\mathrm{TiCE}_{\cdot j}^{r} / \sum_j \mathrm{TiCE}}{\sum_r \mathrm{TiCE}_{\cdot j}^{r} / \sum_r \sum_j \mathrm{TiCE}_{\cdot j}^{r}}. \quad (8)$$

If a region has a relatively large amount of RCA for a specific sector in CO_2 emissions, this region exports relatively more CO_2 emissions from the sector to other regions compared with the region's other sectors and the national average level. This RCA indicator also reveals a region's relative specialization level in a specific sector as measured by CO_2 emissions.

3 Empirical Analyses

The main data sources used in this study to calculate domestic CEiT and TiCE include the 2002 and 2007 Chinese multiregional I/O (CMRIO) tables and the database of Chinese provincial energy-use and CO_2 emissions by sectors. The CMRIO tables are compiled by the China State Information Center (SIC) in 2012 (Zhang and Qi, 2012). The environmental data is calculated from the combustion of fuels and industrial processes using the Intergovernmental Panel on Climate Change (IPCC) reference approach. This study also uses fuel data from China Energy Statistical Yearbooks and China Provincial Statistical Yearbooks. Appendix 1 and Table 1 display the region and sector classifications used in CMRIO. The energy-use and CO_2 emissions data for 44 industries and 30 provinces are aggregated to match the CMRIO classification.

In this section, we first examine the regional value-added and inter-regional trade information obtained from 2002 and 2007 CMRIO data. This information provides an overall view of China's regional economies and inter-regional economic interdependency. Second, we present the region-level and sector-level energy-use and CO_2 emissions to examine the energy-use elasticity of CO_2 emissions. Third, we use the region-level CEiT indicator to demonstrate how a region's participation degree and position in both domestic and international supply chains affect its CO_2 emissions. Fourth, we calculate the results of domestic TiCE for 2002 and 2007 to illustrate the evolution of regional give-out and gain potentials for CO_2 emissions within China's multi-regional production networks. We also use the TiCE sector-level results to evaluate the comparative advantage in CO_2 emissions for different sectors across regions. Finally, we present each region's CO_2 emissions caused by its partner region's exports to show how the linkages between China's domestic supply chains and global markets function in inter-regional spillover of CO_2 emissions.

3.1 China's regional economies and inter-regional trade

As an overall view of the evolution of China's regional economies between 2002 and 2007, we calculate the regional value-added and its real growth rate by sector. Table 1 displays the results. At the national level, total value-added increased by 70% over five years. This is not surprising and coincides with the general image of China's economic performance because the officially published average annual GDP growth rate is roughly 11%[5]. However, the growth rate of value-added at the region and sector levels reveals large variations. At the regional level, the Northwest, the largest energy-base region, exhibits the highest growth rate at 95%, followed by the two developed coastal regions, the North Coast and the East Coast with the same levels of growth rate—79%. The North Municipalities, one of the quickly expanding urban agglomeration areas, also exhibits a higher growth rate at 73%. The growth rates of the Central region (68%), the Southwest (65%),and the South Coast (64%) are close to the national average (71%), while the Northeast (55%) exhibits a relatively low performance in value-added growth.

By comparing regions to the national average as shown in Table 1, we can identify the leading regions for value-added growth by sector. For example, the coastal regions (North Coast and East Coast) can be considered leading regions because their growth rates for most sectors are higher than the national average. The bottom of Table 1 displays sectors that are most important to regional economic growth. Manufacturing sectors such as Other manufacturing products, Non-metallic mineral products, Metal products, Electric appliances and electronics, and Transport equipment play a leading role in most regions. This implies that a similar economic growth pattern exists across regions. However, a relatively clear trend toward specialization appears for primary and household consumption products. For example, the Mining and Food sectors in the Northwest, Textiles in the South Coast and Southwest, and Wood products in the North Coast exhibit high growth rates relative to that in the corresponding sectors in other regions.

The dynamics and diversity of regional and sectoral economic growth depend not only on changes in intra-regional production technology but also on inter-regional production networks (including linkages to overseas markets). Figure 1 illustrates the share of bilateral trade in total inter-regional trade for 2002 and 2007, with the bubble size representing the share. To focus on the magnitude of inter-regional trade, this figure excludes intra-regional trade and considers the rest of the world (ROW) as one region. There are no significant structural changes in the inter-regional trade pattern during this five-year period. The exports and imports of the coastal regions account for a relatively large share. Interaction among the coastal regions and between the coastal and central region is the most important element of domestic inter-regional trade. However, a careful comparison of the results from 2002 and 2007 can help us conclude a number of interesting differences. For example, in 2007, the East Coast replaced the South Coast as the leading region in export and import markets. The interaction between the North Municipalities and its neighbor region, the North Coast, also exhibits a dramatic increase during these five years. The Northwest clearly exhibits an increasing magnitude of outflow to coastal regions, as do the coastal regions to the Central region. This makes the overall transaction between regions much flatter

[5] If the annual growth rate of GDP is 11.2% across five years and the first year GDP is 100, the fifth year GDP can be calculated as $(1+11.2\%)^5 \times 100=170$. This means the 5-year GDP growth rate is simply $(170-100)/100 = 70\%$.

in general (with most small bubbles in 2002 growing larger in 2007).

To investigate the degree of dispersion or concentration of inter-regional trade at the sector level, we calculate the coefficient of variation (CV) for intermediate and final products separately by sector. In statistics, CV is defined as the ratio of the standard deviation to the mean of a dataset. CV is a normalized measure of the dispersion of data points in a data series around the mean. It is a useful statistic for comparing the degree of variation from one data series to another, even if the means are drastically different. In our data, a higher CV indicates a higher concentration of trade. According to the results displayed in Table 2, two important features of the changing patterns of inter-regional trade can be summarized as follows. (1) The concentration of total trade in intermediate products across regions decreased (CV fell from 1.03 to 0.97). However, at the sector level, we confirm a wide variation in the change of the concentration degrees reflecting the increasing complexity of inter-regional production networks in China. (2) For most final products, the concentration of inter-regional flows increased rapidly, implying that more regions tend to specialize in production or procurement of final products within the domestic supply chains.

3.2 Regional energy-use, CO_2 emissions, and energy-use elasticity of CO_2 emissions

Table 3 displays energy-use by region and sector for 2002 and 2007. At the regional level, the share of regional energy-use in the national total remains stable across this span of years. When comparing data in Table 3 to the regional value-added scale in Table 1, we observe that regions with relatively large economic scale tend to consume much more energy. For example, the Central region, the East Coast, and the North Coast show large figures for both energy-use and value-added scale. However, when we observe the regions' ranking in energy-use and value-added scale, we find other interesting points. For example, the North Coast ranks fourth in value-added scale, but its ranking in energy-use is the second largest in the nation in 2007. Similarly, the Central region's value-added scale is roughly 93% of that of the East Coast region, whereas its energy-use is roughly 1.4-fold of the East Coast's. This fact implies that the industrial structure and energy use efficiency across regions may also play an important role in determining the size of energy-use.

In contrast, energy-use by sector at the national level does not exhibit a significant structural change. Specifically, Electricity, gas, and water supply account for nearly half of the national energy-use, followed by Metal products (10.0%), Trade and transportation (8.8%), Chemicals (7.7%), and Other services (4.6%) in 2007. However, when examining the energy-use growth rate by region and sector, we observe a relatively large variation. For the ease in identifying the important regions and sectors in the energy-use evolution, we compare the figures of regions to the national average by sector. As shown in the two lower sub-tables of Table 3, the East Coast can be considered the most important driving force of energy-use, because most sectors in this region exhibit relatively faster growth rates compared with the national average. The North Coast and the Northwest also can be identified as primary driving forces of energy consumption at the national level, but these forces are largely supported by several leading sectors.

The compared results for the sectoral average show that Trade and transportation, Electric appliances and electronics, General machinery, and Wood products and furniture can be considered the most important leading forces causing the overall increase of energy-use.

In principal, if the efficiency of energy-use is fixed, a large amount of energy-use is supposed to be accompanied by large CO_2 emissions. Therefore, when examining Table 4, we can easily confirm that the structure of CO_2 emissions and its changing pattern by region and sector are parallel to that of energy-use. However, when comparing these two tables in detail, many differences remain apparent. Here, we calculate the energy-use elasticity of CO_2 emissions (the percentage change of CO_2 emissions/the percentage change of energy-use) by region and sector, results of which are shown in Table 5. This elasticity can be considered as a proxy for evaluating the change in the efficiency of energy-use. Obviously, the national total energy-use efficiency reveals a marginally decreasing trend (1.03). At the regional level, nearly all regions' efficiency decreases between 2002 and 2007. The North Coast, the Northwest, and the Southwest seem to exhibit the worst efficiency levels, while the South Coast is unique in improved energy-use efficiency. At the sectoral level, we observe large variations. Most obviously, the large figure for Other manufacturing products (1.5) catches our immediate attention. However, given its low share in national total CO_2 emissions (0.2%), its impact on the national total are very limited in real terms. Agriculture, several light industries (Food, Textile, Wood and Pulp), General machinery, and Other services also exhibit bad performance. More auspiciously, the most important sectors that account for a large share of CO_2 emissions, like Chemicals, Non-metallic mineral products, Metal products, and Electricity, gas, and water supply exhibit relatively good performance of efficiency of energy-use, assumed to be the primary reason for a "not too bad" marginal change in national total efficiency.

3.3 Regional CO_2 emissions in trade (CEiT)

Figure 2 illustrates China's regional CEiT indicators for 2002 and 2007. At the absolute level, the three developed coastal regions (East Coast, South Coast, and North Coast) have higher embodied CO_2 emissions in export than the inland regions and the North Municipalities (see the top part of Figure 2). These coastal regions are foreign export-oriented economies with a large share of manufacturing exports in their total products, explaining the higher figures of these three coastal regions. It comes as no surprise that the North Municipalities have a low CEiT, given the region's special industrial structure and services-oriented export economy. When analyzing the changing CEiT pattern in terms of export, the East Coast, the North Coast, and the Northwest show a significant increasing trend, largely resulting from their increasing export dependency (see Figure 1) and decreasing energy-use efficiency (see Table 5).

The CEiT figures for outflow in all regions (the second upper part of Figure 2) are much larger than the figures for export in 2007. This clearly indicates that the domestic inter-regional trade has been the major source of regional CEiT. By separating the outflow by intermediate products and final products, we observe that intermediate products play a dominant role in embodied CO_2 emissions. This result is consistent with the fact that many more inland regions have been deeply involved in domestic supply chains by providing more intermediate products to other regions (see Meng et al., 2012). In addition, the decreasing efficiency of energy-use in these inland regions also spurs on these regions' increasing trend in CO_2 emissions caused by the production of outflow goods. The changing pattern of outflow-related CEiT also vastly differs from the export-related CEiT. For the CEiT in outflow of intermediate products, the North Coast and the Central region exhibit both the largest absolute values and fastest change rates, largely resulting from two factors. (1) These two regions are likely to be located at the downstream of inter-regional supply chains by providing a large proportion of intermediate products to other regions. (2) These intermediate products are concentrated largely in Chemicals, Non-metallic products, and Metal products whose production requires relatively more energy and so predictably embodies more CO_2 emissions. For final products, the Northwest and the Northeast also have both the largest absolute value and the fastest change rates of CEiT in outflow simply because these two regions' production process of final products has been more energy-use oriented as they represent China's primary energy base.

Figure 3 illustrates the embodied CO_2 emissions in sectoral export and outflow for 2002 and 2007. Obviously, Metal products and the Chemicals have the largest embodied CO_2 emissions for both export and outflow. Electric appliances and electronics, and Textiles and garments have large figures for export, whereas Electricity, gas, and water supply, and Mining and quarrying have large figures for outflow. These results reflect the fact that Electric appliances and Textiles are both China's major export products, given their high comparative advantage from lower labor cost, whereas Electricity and Mining are always in undersupply and primarily serve domestic demand rather than foreign use. In addition, when analyzing the lower two sub-figures in Figure 3, we easily observe that the CEiT for outflow of intermediate products are the major source of embodied CO_2 emissions and that only service sectors exhibit large figures for final products outflow.

3.4 Inter-regional trade in CO_2 emissions (TiCE)

In the previous section, we calculated the regional CEiT indicator to measure the embodied CO_2 emissions in a specific region or product. This indicator can be estimated if the regional I/O table is available. However, it is difficult to examine the structure of cross-regional flow of CO_2 emissions in detail, because the inter-regional spillover and feedback effects in the production networks cannot be explicitly captured when using only a single regional I/O table. In this section, we applied the concept of domestic TiCE as defined in equation (4) to China's MRIO tables for 2002 and 2007. The results of the TiCE related indicators can explain how CO_2 emissions are created and distributed across regions through inter-regional production networks.

To first check the relative magnitude of regional TiCE, we calculate the proportion of bilateral TiCE in total TiCE and display the results in the middle section of Table 6. Clearly, in 2002, the Central region was the largest exporter of CO_2 emissions (26.89%), followed by the Southwest (15.05%); the North Municipalities was the largest importer (17.59%), followed by the North Coast (16.36%). However, by 2007, significant changes had occurred. Specifically, the Northwest (18.64%) became the second largest exporter; the Central region (23.58%) replaced the North Municipalities as the largest importer, followed by the East Coast (20.92%). The changes in bilateral TiCE can also be confirmed by looking at the TiCE trade balance (deficit and surplus) (see the lower sub-table in Table 6). Obviously, in 2002, the North Municipalities had the largest TiCE deficit, while the Central had the largest TiCE surplus. However, by 2007, the East Coast's deficit and the Northwest's surplus rose to the top.

The detailed evolution of inter-regional TiCE can easily be confirmed from Figure 4. The total national TiCE increased from 748.63 to 2064.05 million metric tons, revealing a dramatic change in magnitude. When analyzing the structural change, we can consider the East Coast and the South Coast as a kind of "pure importer" of CO_2 emissions in both 2002 and 2007. The Central region retains its leading role as a kind of "transmission channel" of CO_2 emissions from inland regions to coastal regions. This function is related to both the Central region's large economy and final demand scale as well as its hub function and position in China's domestic supply chains due to its geographic centrality and well-developed transportation infrastructure. This centrality places it in a prime position to be both an important consumer and supplier of intermediate products in China's domestic supply chains. The North Coast also shows a kind of hub function in the inter-regional TiCE, especially for Northern China. There are clear structural changes that occurred between 2002 and 2007 for the three North regions (North Municipalities, Northeast, and Northwest). As discussed before, the North Municipalities have experienced rapid urbanization accompanying high levels of service-oriented economic structure change. This region's specialization in the production of services and high per capita income level also imply that this region has tended to purchase many more final goods from other regions rather than produce them locally by the intake of intermediate goods shipped from other regions. The production capacity of this urban area has shifted to its neighbor region, the North Coast, explaining the North Municipalities' lost linkages of CO_2 emissions from the Northeast, the Northwest, and the Southwest. This finding also supports the conclusion that the North Coast has enhanced its hub position in North China's TiCE. The Northeast and the Northwest have also become a kind of "pure exporter" of CO_2 emissions in the inter-regional TiCE framework because these two important energy base regions have been able to provide many more highly processed intermediate goods to support other regions' supply chains rather than providing only energy-oriented materials. As a result of these North regions' industrial upgrades, the increasing energy-use for producing intermediate goods understandably causes relatively large CO_2 emissions. In general, the changing pattern of regional TiCE structure depends on a combination of reasons such as (1) economic scale, especially regional demand for final products, (2) a region's position and participation degree in domestic supply chains, (3) regional industry structure, and (4) energy-use and CO_2 emissions as well as energy-use efficiency across regions.

To measure the regional TiCE performance in China's domestic supply chains, we divide the bilateral TiCE by the bilateral TiVA and display the results in the lower section of Table 6. According to the concepts of TiCE and TiVA, we easily observe that a larger ratio (TiCE/TiVA) means that the origin region pays a relatively large environmental costs but gains a small value-added in domestic supply chains. For example, in 2002, the value in the cell at the intersection of the Northwest's row and the

North Municipalities' column is 9.6 indicating that when the North Municipalities' final demand causes 10 thousand Chinese yuan value-added in the Northwest region, the Northwest bears 9.6 metric tons of CO_2 emissions. At the national level, the overall performance of cross-region CO_2 emissions during the five years (2002–2007) depicts a marginally decreasing trend because the TiCE per TiVA increases from 4.0 to 4.3. At the regional level, the North Municipalities, the Northwest, and the Southwest exhibit improved performance because of their ability to export value-added with relatively lower CO_2 emissions. However, at the absolute level, these regions' TiCE per TiVA remains larger than those of the East Coast and South Coast. This phenomenon results primarily from their different position in domestic supply chains as well as the variation in production techniques across regions.

As described in the previous section, the total TiCE can be separated into two ($\mathrm{TiCEF}^{rs} + \mathrm{TiCEH}^{rs}$). Table7 presents the TiCE matrix caused by regional final demand for its locally produced products. For example, in 2002, the value in the cell at the intersection of the North Municipalities' column and the North Coast's row is 35.47, indicating that the North Municipalities' final demand for products produced in its own region created roughly 35.47 million metric tons of CO_2 emissions in the North Coast in 2002. Moving lower in the column, we see that the sum of roughly 87.78 million metric tons represents the total CO2 emissions creation effect that the North Municipalities exert on other regions as a whole. We divide the column sum of the North Municipalities by the average of each region's column sum to produce an index for the North Municipalities. We call this index the North Municipalities'" CO_2 emissions give-out potential." Similarly, the 2002 row total of the North Coast (77.68) represents the total CO_2 emissions of the North Coast caused by the other regions as a whole. Again, we use the row sum to define the North Coast's "CO_2 emissions gain potential."

To illustrate the development of the TiCE structure from 2002 through 2007, the above mentioned two potentials of each region are plotted in Figure 5. The position of the East Coast demands immediate attention. The East Coast, with its large economic scale and highest per capita GDP in China, purchases a massive amount of goods and services from its home market, generating significant CO_2 emissions in other regions, especially in its neighbor, the Central region (see Table 3). Thus, the East Coast has relatively strong backward linkages of the creation of CO_2 emissions with the Central region. The Central region has the largest gain potential related to its downstream-location in domestic supply chains supported by its geographic centrality and well-developed transportation accessibility. This centrality places it in a prime position to be a supplier of intermediate products to other regions, especially those on the coast. In general, the position of a region in Figure 5 depends on both its economic scale and its role in domestic supply chains. Analyzing the changes in each region, we observe that the East Coast quickly enhanced its give-out potentials as a CO_2 emissions importer. This behavior implied that the East Coast's final demand for their locally made products tends to create backward CO_2 emissions linkages with remote and smaller regions who is located in the upstream of supply chains by providing more intermediate products. The Northwest region, meanwhile, moved in the opposite direction as it increased its gain potential and decreased its give-out potential. This phenomenon can be explained in two ways: (1) The Northwest region, as China's largest energy base, has been able to provide many more intermediate products that require a relatively large amount of energy inputs. This fact explains the Northwest's increased gain potential and the movements of the Northeast and North Coast, both of which are China's major providers of energy-intensive intermediate products. (2) The Northwest region has also been able to provide many more energy-intensive intermediate products of its own for creating local final products rather than using intermediate products shipped from other regions. This gives the Northwest with lower CO_2 emissions give-out potential. The speed with which the North Municipalities' lost the give-out potential is interesting, but not surprising when we consider that the North Municipalities, with the nation's fastest GDP growth, has become a service oriented region but tends to purchase more final goods from other regions rather than needing to intake more energy-intensive intermediate products from other region to produce its local final products.

Table 8 displays the trans-regional CO_2 emissions caused by regional final demand of inflow products ($\mathrm{TiCEF}^{\mathrm{rs}}$) for both 2002 and 2007, representing how much one region's inter-regional demand (demand for final products produced in other domestic regions) causes another region's CO_2 emissions through inter-regional supply chains. In the same manner as shown in Table 7, we calculate the give-out and gain potentials for each region and plot them in Figure 6. We see that the Central region changed its position from the largest exporter to the largest importer of trans-regional CO_2 emissions as measured by inter-regional final demand. This finding reflects two facts: (1) The Central region, as the second largest economy with the best accessibility to the domestic market, has tended to purchase more energy-intensive final products from other regions, causing its partner region's CO_2 emissions. (2) The Central region's relative position in providing energy-intensive intermediate products has been replaced by other energy-rich inland regions, such as the Northwest and the Northeast, making the Central region lose its gain potential in inter-regional CO_2 emissions spillover. The movement of the other regions illustrated in Figure 6 is similar to Figure 5.

In addition, when comparing the national (row sum or column sum) level and its trans-regional CO2 emissions growth rate for locally made final products (124%) and final inflow products (296%), we readily observe that the demand on locally made final products is the dominant source of inter-regional CO_2 emissions spillover, but the demand on final inflow products should be considered the leading force causing the increasing presence of trans-regional CO_2 emissions.

3.5 Evolution of regional comparative advantage measured by domestic TiCE

There is no guarantee that providing more products equals more CO_2 emissions in a supply chain with its domestic trade having a high vertical specialization. This observation becomes crucial when considering regional comparative advantage from the perspective of CO_2 creation within the domestic production networks. Therefore, we use the TiCE concept to measure regional comparative advantage.

Table 9 shows the TiCE based domestic RCA indicator and its changing pattern between 2002 and 2007. The major findings can be summarized as follows. (1) There is a large variation of CO_2 emissions based

RCA by sector across regions. Specifically, the most developed coastal regions (South Coast and East Coast) have relatively more sectors with top ranking RCA, especially in the manufacturing sector; inland regions largely specialize in primary sectors. (2) The ranking of a region in RCA by sector changes significantly between 2002 and 2007. For example, in 2002, the North Municipalities ranks first for Metal products, but in 2007 the North Coast has taken the top position, primarily because the North Coast experienced rapid development of metal-related production over the five year period.

3.6 CO_2 emissions spillover effect caused by another region's exports

As discussed in the previous section, using the inter-regional I/O framework, we can also estimate how much of a region's CO_2 emissions are created by another region's exports. This knowledge can help us understand the CO_2 emission related spillover of a specific region in another region's global supply chains.

Figure 7 shows the give-out potential of CO_2 emissions caused by regional exports. In both 2002 and 2007, the exports of the two developed Coastal regions (South Coast and East Coast) had the largest CO_2 emissions spillover effect on other regions. Analyzing the components of the bars for these two coastal regions' give-out potential, we find that the Central region is the primary emission source region. This finding clearly reflects Central region's role in the coastal regions' global supply chains: the Central region has been the primary provider of highly energy-intensive intermediate products in coastal regions' supply chains of exported products. The absolute level of the East Coast's give-out potential has also been the largest, at nearly double that of the South Coast. This phenomenon can be explained by not only the expanding presence of the East Coast in China's export market (see Figure 1), but also the increasing efficiency of energy-use in the South Coast region (see Table 5). The relative but quite remarkable decrease of the North Municipalities' give-out potential concerning CO_2 emissions supports the fact that this region has experienced rapid post-industrialization and a services-oriented structure change. Analyzing the gain potential of CO_2 emissions caused by regional exports (Figure 8), we observe that the Central region with its large economy and centralized location maintains its position as the largest provider of CO2 emissions caused by other regions' exports. From the East Coast's increased effect on other regions' CO_2 emissions gain potential, we can readily observe that more inland regions have been involved in the East region's export products supply chains by providing many more energy-intensive intermediate products.

4 Concluding Remarks

To explain the relationship between China's regional CO_2 emissions and the increasing complexity of domestic supply chains, this study focused on the measure of inter-regional spillover of CO_2 emissions. Using China's 2002 and 2007 inter-regional Input–output tables and related province-level energy-use, we analyzed CO_2 emission information, the detailed structural changes of CO_2 emissions in trade (export and domestic inter-regional trade), domestic trade in CO_2 emissions, and the regional trade balance of

CO_2 emissions concerning the position and participation degree of different regions in domestic supply chains.

The study's major conclusions can be summarized as follows: (1) The energy-use elasticity of CO_2 emissions at the national level changes very little between 2002 and 2007. This is mainly attributable to the improvement of energy-use efficiency in several important energy-intensive sectors, such as metal products, the non-metallic mineral products, and chemicals. However, at the regional level, the North Coast, the Northwest, and the Southwest exhibit lower performance compared to the North Municipalities and the South Coast. (2) The increasing participation of China's coastal regions in global supply chains rapidly increased embodied CO_2 emissions in regional exports. However, because most inland regions have been deeply involved in domestic supply chains by providing many more intermediate products to other regions, the embodied CO_2 emissions in these regions' outflow have also rapidly increased. (3) Inter-regional trade in CO_2 emissions at the national level roughly tripled between 2002 and 2007 with relatively large structure change among regions. The East Coast became the largest importer of domestic CO_2 emissions; the Central region changed from exporter to importer of CO_2 emissions; and the Northwest became the largest exporter of CO_2 emissions. All these changes reflect the following facts: the East Coast is located in the downstream of domestic supply chains with large backward linkages to inland regions, especially to the Central region; the Central region as the second largest economy and with geographic centrality playing a leading role as a kind of "transmission channel" of CO_2 emissions from inland regions to coastal regions; and the Northeast and Northwest regions have been able to provide many more intermediate products to other regions by using their comparative advantage in energy sectors, which gives them a large surplus in the balance of CO_2 emissions trade. In addition, comparing the trade in CO_2 emission with the trade in value added, performance improvement can be found in the North Municipalities, the Northwest, and the Southwest, because they have been able to "export" much more value-added with relatively small CO_2 emissions in domestic markets, although their absolute CO_2 emissions remain higher than that of coastal regions. (4) The inland regions tend to be able to export a greater quantity of CO_2 emissions not only by increasing direct exports of goods and services to the world market, but also by joining the domestic supply chains of the leading coastal region, especially the East Coast.

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Table 1 China's regional value added by sector and its growth rate (2002-2007)

	Billion Chinese yuan (base year: 2002)	Agriculture	Mining and quarrying	Food products and tobacco	Textile and garment	Wood products and furniture	Pulp, paper, and printing	Chemical	Non-metallic mineral products	Metal products	General machinary	Transport equipment	Electric appliances and electronics	Other manufacturing products	Electricity, gas, and water supply	Construction	Trade and transportation	Other services	Total	Share by region (%)
2002	Northeast	152	134	37	15	12	12	77	3	59	38	37	21	13	47	60	166	276	1,158	9.5
	North Municipalities	19	18	11	8	1	9	33	4	17	13	9	41	8	12	35	77	317	632	5.2
	North Coast	253	107	114	58	8	41	114	37	77	72	23	27	21	48	81	194	396	1,673	13.7
	East Coast	202	21	59	163	16	52	182	29	109	103	67	143	53	84	116	323	695	2,415	19.8
	South Coast	194	43	46	73	35	61	100	22	57	39	25	156	40	66	76	293	554	1,881	15.4
	Central	441	159	92	52	26	38	105	62	113	67	48	33	33	89	139	295	582	2,373	19.5
	Northwest	126	67	17	8	2	7	30	10	32	11	10	8	5	34	66	103	228	766	6.3
	Southwest	276	47	74	9	7	19	45	23	53	22	33	17	11	51	87	160	354	1,286	10.6
	Total	1,663	597	450	386	108	237	686	191	517	365	253	445	185	432	659	1,610	3,402	12,186	100.0
	Share by sector (%)	13.6	4.9	3.7	3.2	0.9	1.9	5.6	1.6	4.2	3.0	2.1	3.6	1.5	3.5	5.4	13.2	27.9	100.0	
2007	Northeast	225	200	57	21	16	9	147	30	82	64	91	26	35	55	100	235	402	1,795	8.6
	North Municipalities	16	43	15	8	2	6	48	7	46	32	27	63	23	32	54	156	519	1,097	5.3
	North Coast	336	230	148	115	51	44	215	119	199	130	71	68	49	91	147	322	662	2,997	14.3
	East Coast	232	21	105	265	38	66	315	68	272	235	127	319	171	119	211	527	1,224	4,313	20.6
	South Coast	243	56	76	166	35	75	177	78	119	71	60	291	93	130	127	374	909	3,078	14.7
	Central	605	219	197	94	50	54	225	130	278	121	58	81	77	155	250	462	933	3,990	19.1
	Northwest	194	244	54	13	4	7	67	26	107	19	15	13	5	75	107	187	362	1,498	7.2
	Southwest	400	71	145	20	10	18	90	35	125	46	56	36	26	97	144	247	557	2,121	10.2
	Total	2,250	1,084	798	702	206	279	1,284	491	1,226	718	505	897	479	753	1,139	2,509	5,569	20,889	100.0
	Share by sector (%)	10.8	5.2	3.8	3.4	1.0	1.3	6.1	2.4	5.9	3.4	2.4	4.3	2.3	3.6	5.5	12.0	26.7	100.0	
Real growth rate (%)	Northeast	48	50	56	43	34	(21)	91	1,077	37	70	145	24	165	16	67	42	45	55	
	North Municipalities	(12)	139	34	(3)	5	(28)	45	83	169	155	199	55	173	170	54	102	64	73	
	North Coast	33	115	30	98	524	8	89	217	159	80	209	157	127	89	81	66	67	79	
	East Coast	15	1	80	63	140	27	73	131	150	127	90	124	224	41	82	63	76	79	
	South Coast	25	28	65	126	(2)	23	76	246	109	83	138	87	132	97	68	28	64	64	
	Central	37	38	115	80	90	44	114	109	147	80	21	147	134	74	80	57	61	68	
	Northwest	54	263	213	70	132	2	123	147	230	68	49	48	4	116	61	82	59	95	
	Southwest	45	50	97	128	48	(3)	102	52	135	111	66	111	133	88	66	54	58	65	
	Total	35	82	78	82	91	18	87	157	137	97	100	102	158	74	73	56	64	71	
Relative to regional average	Northeast	+	-	-	-	-	-	+	+	-	-	+	-	+	-	-	-	-	-	
	North Municipalities	-	+	-	-	-	-	-	-	+	+	+	-	+	+	-	+	-	+	
	North Coast	-	+	-	+	+	-	+	+	+	-	+	+	-	+	+	+	+	+	
	East Coast	-	-	+	-	+	+	-	-	+	+	-	+	+	-	+	+	+	+	
	South Coast	-	-	-	+	-	+	-	+	-	-	+	-	-	+	-	-	+	-	
	Central	+	-	+	-	-	+	+	-	+	-	-	+	-	-	+	+	-	-	
	Northwest	+	+	+	-	+	-	+	-	+	-	-	-	-	+	-	+	-	+	
	Southwest	+	-	+	+	-	-	+	-	-	+	-	+	-	+	-	-	-	-	
Relative to sectoral average	Northeast	-	-	+	-	-	-	+	+	-	+	+	-	+	-	+	-	-		
	North Municipalities	-	+	-	-	-	-	-	+	+	+	+	-	+	+	-	+	-		
	North Coast	-	+	-	+	+	-	+	+	+	+	+	+	+	+	+	-	-		
	East Coast	-	-	+	-	+	-	-	+	+	+	+	+	+	-	+	-	-		
	South Coast	-	-	+	+	-	-	+	+	+	+	+	+	+	+	+	-	+		
	Central	-	-	+	+	+	-	+	+	+	+	-	+	+	+	+	-	-		
	Northwest	-	+	+	-	+	-	+	+	+	-	-	-	-	+	-	-	-		
	Southwest	-	-	+	+	-	-	+	-	+	+	+	+	+	+	+	-	-		
	Total	-	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	-		

Figure 1 Share of bilateral trade in total inter-regional trade
(without considering intra-regional trade)

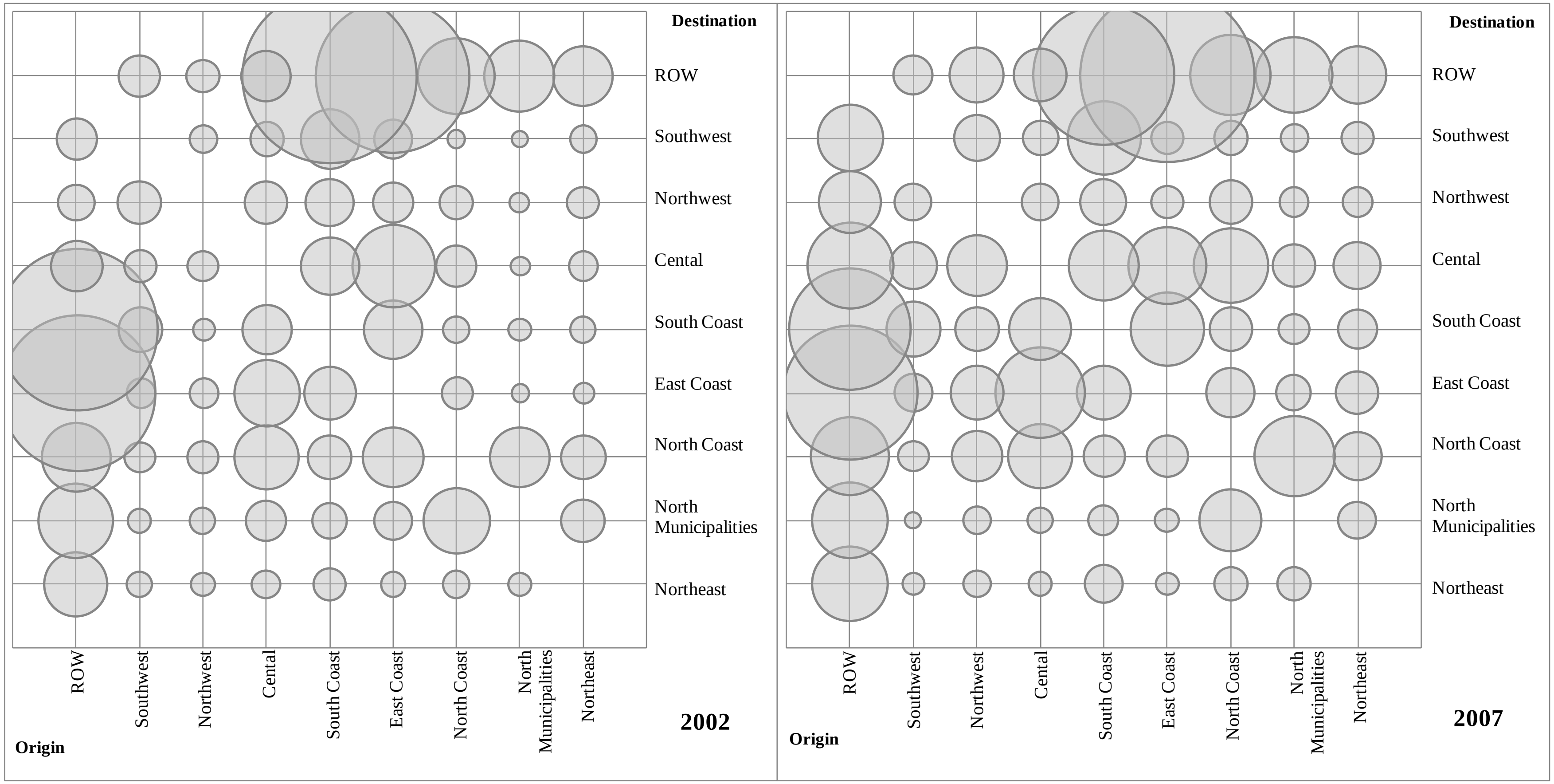


Table 2 Concentration degree (CV) of inter-regional trade in intermediate and final products

Sector	Intermediate products			Final products		
	2002	2007	Change rate	2002	2007	Change rate
Agriculture	1.68	1.81	7.5%	1.66	1.77	7.0%
Mining and quarrying	1.51	1.65	9.5%	2.54	2.43	-4.2%
Food products and tobacco	1.62	1.29	-20.6%	1.29	1.45	12.2%
Textile and garment	1.76	1.56	-11.3%	1.57	3.40	117.2%
Wood products and furniture	1.70	1.78	4.4%	1.86	1.76	-5.5%
Pulp, paper, and printing	1.84	1.78	-3.0%	1.76	3.46	96.1%
Chemical	1.37	1.18	-13.8%	1.19	1.32	10.7%
Non-metallic mineral products	1.99	1.79	-9.9%	1.87	2.06	10.1%
Metal products	1.29	1.42	10.0%	1.51	1.76	16.6%
General machinery	1.80	1.67	-7.6%	1.81	2.07	14.2%
Transport equipment	1.37	1.37	0.4%	1.51	1.61	6.2%
Electric applicances and electronics	1.65	2.43	47.8%	1.83	2.19	19.6%
Other manufacturing products	1.87	1.66	-11.4%	1.70	2.05	20.5%
Electricity, gas, and water supply	2.21	1.90	-13.9%	1.96	2.45	24.9%
Construction	2.39	2.00	-16.4%	1.99	1.77	-11.0%
Trade and transportation	1.23	1.36	10.5%	1.27	1.65	29.5%
Other services	1.76	2.15	22.7%	1.91	2.42	27.0%
Total products	1.03	0.97	-5.7%	0.98	1.11	12.9%

Table 3 China's regional energy use by sector and its growth rate (2002-2007; unit: PJ)

	Unit: PJ	Agriculture	Mining and quarrying	Food products and tobacco	Textile and garment	Wood products and furniture	Pulp, paper, and printing	Chemical	Non-metallic mineral products	Metal products	General machinery	Transport equipment	Electric appliances and electronics	Other manufacturing products	Electricity, gas, and water supply	Construction	Trade and transportation	Other services	Total	Share by region (%)
2002	Northeast	230	261	70	11	11	21	355	134	374	29	26	13	4	2,722	35	299	373	4,968	12.6
	North Municipalities	31	36	24	18	3	10	132	49	169	12	12	11	3	691	19	189	251	1,659	4.2
	North Coast	180	204	118	94	16	88	459	384	463	59	29	22	16	2,898	130	31	299	5,488	14.0
	East Coast	173	39	40	129	6	23	287	151	266	49	26	26	8	3,571	50	603	228	5,675	14.4
	South Coast	87	13	114	86	8	76	79	305	165	17	15	23	20	2,356	14	393	325	4,096	10.4
	Central	284	491	73	52	10	60	755	455	501	52	84	12	9	4,791	68	542	420	8,659	22.0
	Northwest	123	238	46	15	1	36	286	151	208	40	17	10	7	2,764	72	261	272	4,549	11.6
	Southwest	166	329	36	7	2	10	364	144	672	21	52	6	11	1,641	39	372	358	4,230	10.8
	Total	1,274	1,612	521	412	58	325	2,718	1,773	2,818	279	261	122	77	21,436	427	2,690	2,525	39,324	100.0
	Share by sector (%)	3.2	4.1	1.3	1.0	0.1	0.8	6.9	4.5	7.2	0.7	0.7	0.3	0.2	54.5	1.1	6.8	6.4	100.0	
2007	Northeast	203	348	225	26	31	41	746	294	853	92	76	21	27	3,736	59	637	420	7,836	11.1
	North Municipalities	30	39	32	11	2	10	172	57	183	18	20	10	8	903	33	310	379	2,218	3.2
	North Coast	206	300	327	232	47	211	870	525	2,054	165	55	108	18	5,661	59	769	320	11,926	17.0
	East Coast	183	94	87	334	31	209	761	374	768	130	51	76	12	5,829	91	1,280	435	10,745	15.3
	South Coast	137	48	93	205	17	207	346	663	354	35	22	123	22	3,101	34	785	512	6,704	9.5
	Central	347	802	369	95	46	243	1,458	976	1,756	157	99	58	26	7,235	121	1,017	440	15,245	21.7
	Northwest	164	611	154	20	5	51	498	170	576	25	13	23	3	5,081	85	615	412	8,506	12.1
	Southwest	255	295	205	54	13	96	550	508	485	60	47	16	6	3,323	83	790	330	7,114	10.1
	Total	1,525	2,537	1,492	977	192	1,067	5,401	3,568	7,029	683	382	434	121	34,869	565	6,203	3,248	70,295	100.0
	Share by sector (%)	2.2	3.6	2.1	1.4	0.3	1.5	7.7	5.1	10.0	1.0	0.5	0.6	0.2	49.6	0.8	8.8	4.6	100.0	
Growth rate (%)	Northeast	(12)	33	222	139	180	92	110	119	128	215	189	65	653	37	69	113	13	58	
	North Municipalities	(2)	9	32	(38)	(15)	1	30	18	8	51	70	(9)	160	31	71	64	51	34	
	North Coast	15	47	178	147	190	138	89	37	344	179	92	393	14	95	(55)	2,397	7	117	
	East Coast	6	141	120	160	391	797	165	147	189	165	93	191	59	63	83	112	91	89	
	South Coast	58	275	(19)	138	119	172	340	117	114	106	44	438	9	32	137	100	58	64	
	Central	22	63	407	84	358	306	93	115	250	203	17	383	199	51	77	88	5	76	
	Northwest	33	157	232	29	242	44	74	12	177	(36)	(23)	129	(60)	84	18	135	52	87	
	Southwest	54	(11)	468	672	572	825	51	253	(28)	191	(9)	179	(49)	102	115	113	(8)	68	
	Total	20	57	187	137	234	229	99	101	149	145	47	257	58	63	32	131	29	79	
Relative to regional ave	Northeast	-	-	+	+	-	-	+	+	-	+	+	-	+	-	+	-	-	-	
	North Municipalities	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-	
	North Coast	-	-	-	+	-	-	-	-	+	+	+	+	-	+	-	+	-	+	
	East Coast	-	+	-	+	+	+	+	+	+	+	+	-	+	+	+	-	+	+	
	South Coast	+	+	-	+	-	-	+	+	-	-	-	+	-	-	+	-	+	-	
	Central	+	+	+	-	+	+	-	+	+	+	-	+	+	-	+	-	-	-	
	Northwest	+	+	+	-	+	-	-	-	+	-	-	-	-	+	-	+	+	+	
	Southwest	+	-	+	+	+	+	-	+	-	+	-	-	-	+	+	-	-	-	
Relative to sectoral average	Northeast	-	-	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-		
	North Municipalities	-	-	-	-	-	-	-	-	-	+	+	-	+	-	+	+	+		
	North Coast	-	-	+	+	+	+	-	-	+	+	-	+	-	-	-	+	-		
	East Coast	-	+	+	+	+	+	+	+	+	+	+	+	-	-	-	+	+		
	South Coast	-	+	-	+	+	+	+	+	+	+	-	+	-	-	+	+	-		
	Central	-	-	+	+	+	+	+	+	+	+	-	+	+	-	+	+	-		
	Northwest	-	+	+	-	+	-	-	-	+	-	-	+	-	-	-	+	-		
	Southwest	-	-	+	+	+	+	-	+	-	+	-	+	-	+	+	+	-		
	Total	-	-	+	+	+	+	+	+	+	+	-	+	-	-	-	+	-		

Table 4 China's regional CO2 emissions by sector (2002-2007; unit: million metric tons)

	Unit: million metric tons	Agriculture	Mining and quarrying	Food products and tobacco	Textile and garment	Wood products and furniture	Pulp, paper, and printing	Chemical	Non-metallic mineral products	Metal products	General machinary	Transport equipment	Electric appliances and electronics	Other manufacturing products	Electricity, gas, and water supply	Construction	Trade and transportation	Other services	Total	Share by region (%)
2002	Northeast	16	18	5	1	1	2	25	31	66	2	2	1	0	228	3	21	25	447	11.7
	North Municipalities	2	3	2	1	0	1	12	10	29	1	1	1	0	57	1	13	16	151	4.0
	North Coast	13	16	9	7	1	7	45	103	86	5	2	2	1	245	10	2	20	573	15.0
	East Coast	12	3	2	9	0	2	38	72	45	3	2	2	1	300	3	44	13	551	14.4
	South Coast	6	1	8	6	0	5	13	71	27	1	1	1	1	193	1	28	18	382	10.0
	Central	21	38	5	4	1	5	62	119	147	4	7	1	1	408	5	38	28	893	23.4
	Northwest	9	17	3	1	0	3	22	36	36	3	1	1	0	232	5	18	18	405	10.6
	Southwest	13	27	2	0	0	1	31	62	82	1	4	0	1	139	3	26	22	414	10.9
	Total	93	121	38	29	4	24	249	504	518	21	19	8	5	1,803	32	190	159	3,816	100.0
	Share by sector (%)	2.4	3.2	1.0	0.8	0.1	0.6	6.5	13.2	13.6	0.5	0.5	0.2	0.1	47.2	0.8	5.0	4.2	100.0	
2007	Northeast	15	25	17	2	2	3	57	62	123	7	6	2	2	313	5	45	28	714	10.3
	North Municipalities	2	3	2	1	0	1	13	11	40	1	1	1	1	75	2	22	24	200	2.9
	North Coast	15	22	25	18	4	16	69	167	374	13	4	8	1	471	4	55	21	1,287	18.6
	East Coast	13	7	6	25	2	16	57	147	149	10	3	4	1	485	6	93	27	1,052	15.2
	South Coast	10	3	7	15	1	15	24	129	50	2	1	7	1	252	2	55	32	608	8.8
	Central	26	62	28	7	4	19	117	251	294	13	8	4	2	598	9	72	29	1,543	22.3
	Northwest	12	41	12	1	0	4	36	66	96	2	1	2	0	425	7	43	28	775	11.2
	Southwest	20	22	15	4	1	7	39	137	120	4	3	1	0	276	6	56	22	733	10.6
	Total	112	186	113	72	14	81	413	969	1,246	53	28	28	9	2,895	41	441	211	6,913	100.0
	Share by sector (%)	1.6	2.7	1.6	1.0	0.2	1.2	6.0	14.0	18.0	0.8	0.4	0.4	0.1	41.9	0.6	6.4	3.0	100.0	
Growth rate (%)	Northeast	-6	36	227	163	184	101	124	98	86	228	198	75	995	37	72	115	14	60	
	North Municipalities	1	4	34	-40	-20	1	7	5	40	47	60	-26	156	30	79	62	49	32	
	North Coast	10	43	179	143	199	139	53	63	335	177	92	419	16	92	-58	2,785	7	125	
	East Coast	7	167	175	176	508	890	50	102	235	198	84	148	45	62	86	113	108	91	
	South Coast	63	325	-19	162	116	185	86	82	85	84	35	645	78	30	152	97	72	59	
	Central	19	64	416	94	393	316	90	112	100	217	21	389	211	47	72	89	5	73	
	Northwest	33	147	264	37	350	51	66	83	166	-35	-16	121	-53	83	22	135	57	91	
	Southwest	57	-17	630	887	617	965	26	120	45	195	-18	185	-45	99	119	114	-1	77	
	Total	21	53	201	149	253	240	66	92	141	154	45	269	87	61	30	132	32	81	
Comparing to regional a	Northeast	-	-	+	+	-	-	+	+	-	+	+	-	+	-	+	-	-	-	
	North Municipalities	-	-	-	-	-	-	-	-	-	-	+	-	+	-	+	-	+	-	
	North Coast	-	-	-	-	-	-	-	-	+	+	+	+	-	+	-	+	-	+	
	East Coast	-	+	-	+	+	+	-	+	+	+	+	-	-	+	+	-	+	+	
	South Coast	+	+	-	+	-	-	+	-	-	-	-	+	-	-	+	-	+	-	
	Central	-	+	+	-	+	+	+	+	-	+	-	+	+	-	+	-	-	-	
	Northwest	+	+	+	-	+	-	-	-	+	-	-	-	-	+	-	+	+	+	
	Southwest	+	-	+	+	+	+	-	+	-	+	-	-	-	+	+	-	-	-	
Comparing to sectoral aver	Northeast	-	-	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-		
	North Municipalities	-	-	+	-	-	-	-	-	+	+	+	-	+	-	+	+	+		
	North Coast	-	-	+	+	+	+	-	-	+	+	-	+	-	-	-	+	-		
	East Coast	-	+	+	+	+	+	-	+	+	+	-	+	-	-	-	+	+		
	South Coast	+	+	-	+	+	+	+	+	+	+	-	+	+	-	+	+	+		
	Central	-	-	+	+	+	+	+	+	+	+	-	+	+	-	-	+	-		
	Northwest	-	+	+	-	+	-	-	-	+	-	-	+	-	-	-	+	-		
	Southwest	-	-	+	+	+	+	-	+	-	+	-	+	-	+	+	+	-		
	Total	-	-	+	+	+	+	-	+	+	+	-	+	+	-	-	+	-		

Table 5 Energy use elasticity of CO_2 emissions by region and sector (2002-2007)

		Agriculture	Mining and quarrying	Food products and tobacco	Textile and garment	Wood products and furniture	Pulp, paper, and printing	Chemical	Non-metallic mineral products	Metal products	General machinary	Transport equipment	Electric appliances and electronics	Other manufacturing products	Electricity, gas, and water supply	Construction	Trade and transportation	Other services	Total
region	Northeast	0.48	1.09	1.02	1.17	1.03	1.10	1.13	0.83	0.67	1.06	1.05	1.16	1.52	1.00	1.04	1.02	1.11	1.04
	North Municipalities	-0.39	0.51	1.05	1.04	1.36	1.23	0.24	0.29	4.74	0.91	0.85	2.89	0.97	0.99	1.11	0.98	0.95	0.96
	North Coast	0.67	0.92	1.01	0.98	1.05	1.01	0.59	1.70	0.97	0.99	1.00	1.07	1.12	0.97	1.06	1.16	1.04	1.06
	East Coast	1.22	1.19	1.46	1.10	1.30	1.12	0.30	0.70	1.24	1.20	0.90	0.77	0.77	0.97	1.04	1.01	1.19	1.02
	South Coast	1.09	1.18	1.05	1.17	0.97	1.07	0.25	0.70	0.75	0.80	0.78	1.47	8.34	0.96	1.11	0.98	1.25	0.93
	Central	0.86	1.01	1.02	1.12	1.10	1.03	0.96	0.97	0.40	1.07	1.22	1.01	1.06	0.92	0.93	1.01	1.09	0.96
	Northwest	1.02	0.94	1.14	1.30	1.45	1.16	0.89	6.76	0.94	0.96	0.71	0.94	0.89	0.99	1.24	1.00	1.10	1.05
	Southwest	1.05	1.64	1.35	1.32	1.08	1.17	0.51	0.47	-1.63	1.02	1.90	1.03	0.93	0.96	1.03	1.02	0.12	1.13
	Total	1.06	0.93	1.08	1.08	1.08	1.05	0.67	0.91	0.94	1.07	0.98	1.05	1.48	0.97	0.92	1.01	1.12	1.03

Figure 2 China's Regional CO2 emissions in trade (2002-2007)

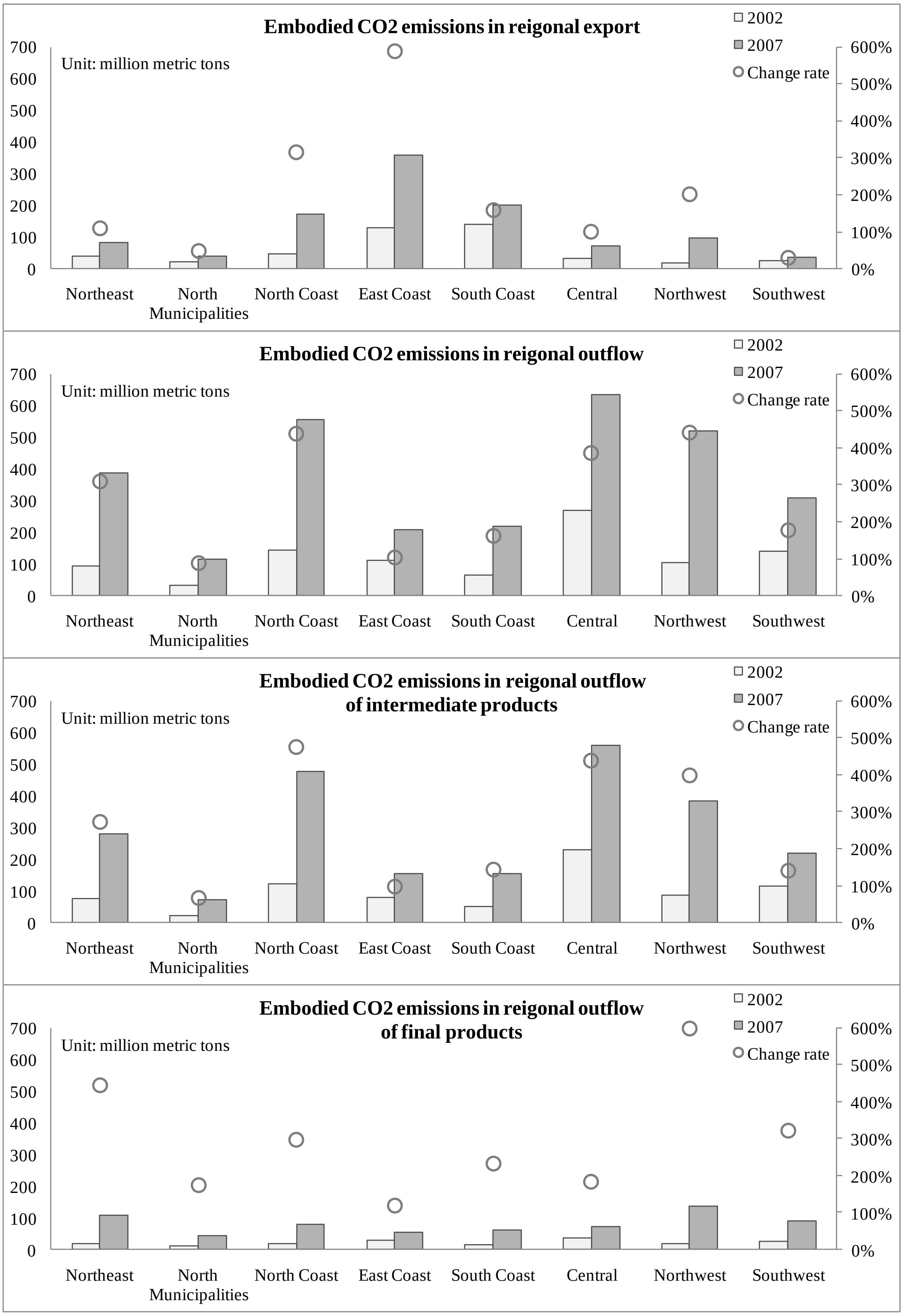


Figure 3 China's Embodied CO2 emissions in trade by sector (2002-2007)

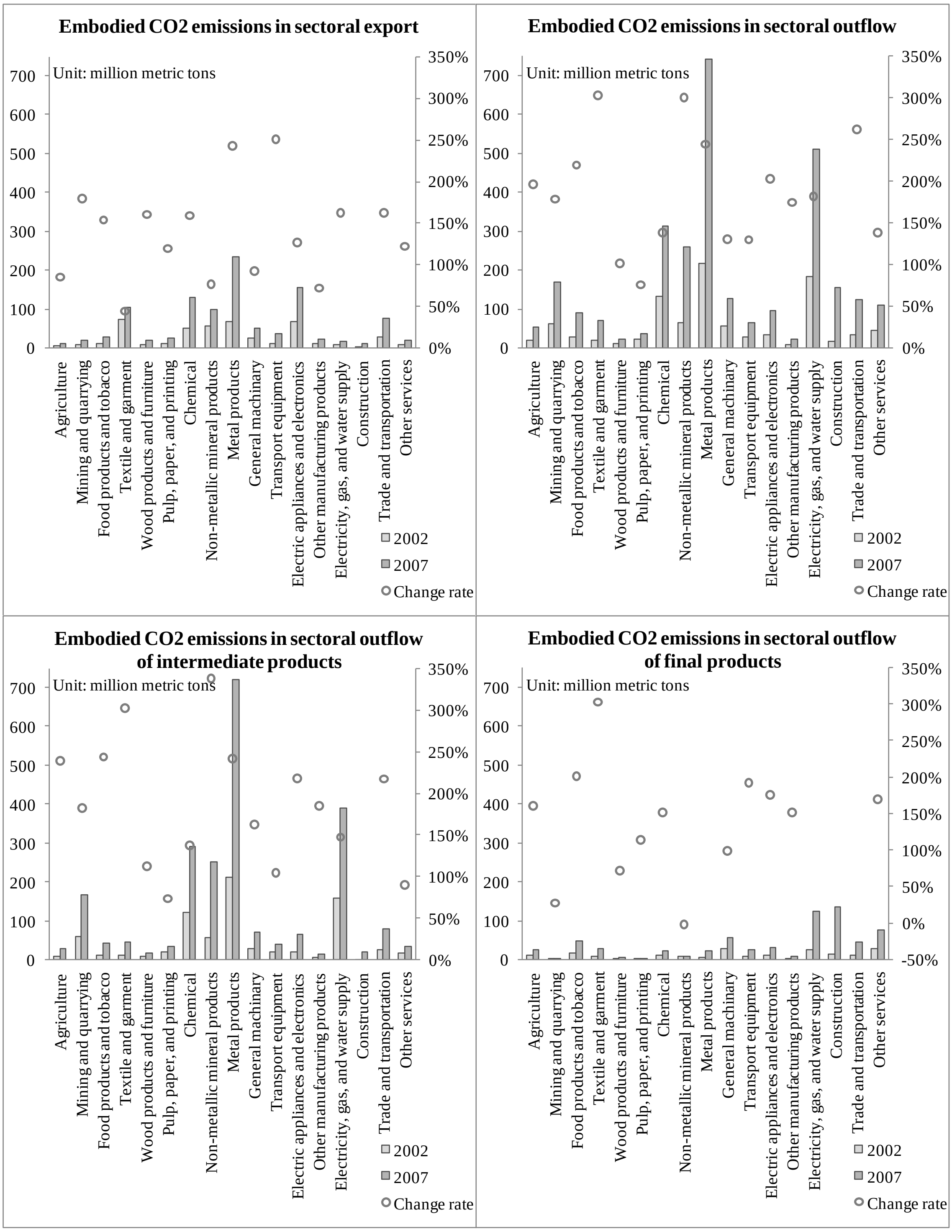
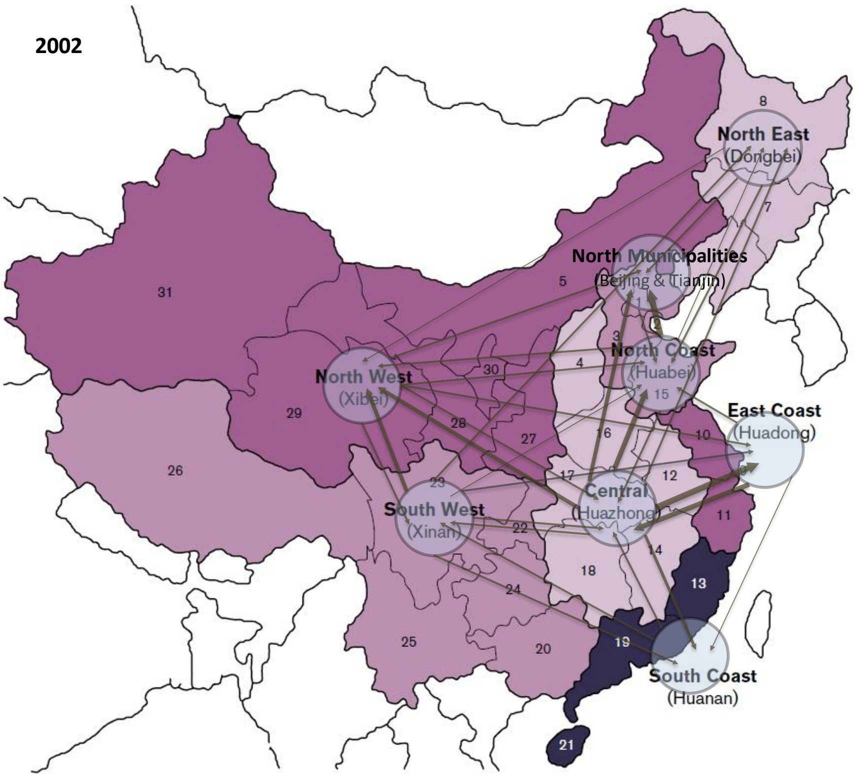


Table 6 Inter-regional trade in CO2 emissions (TiCE) and the TiCE balance (2002 -2007)

	Interregional trade in CO2 emissions (million metric tons)																	
	2002									2007								
	NE	NM	NC	EC	SC	CE	NW	SW	Toal	NE	NM	NC	EC	SC	CE	NW	SW	Toal
Northeast		16.81	19.19	5.25	5.53	9.86	10.64	7.72	75.01		26.53	66.05	47.44	25.28	78.88	19.00	24.92	288.11
North Municipalities	2.33		14.02	1.63	1.04	2.57	2.38	1.49	25.46	7.45		39.76	10.94	5.68	15.85	5.34	6.30	91.33
North Coast	10.40	48.08		9.01	4.93	13.93	12.94	3.80	103.08	31.15	54.53		69.33	34.50	114.91	31.20	33.52	369.13
East Coast	3.44	7.97	17.28		11.48	35.02	9.64	8.42	93.25	6.79	4.77	19.32		29.71	60.15	9.79	14.94	145.47
South Coast	3.33	4.22	6.63	8.62		12.14	8.71	12.75	56.40	11.66	4.95	14.94	29.80		45.39	14.76	42.22	163.73
Central	16.30	29.88	39.94	46.16	24.02		29.65	15.40	201.34	19.84	17.52	89.66	157.13	49.90		27.98	35.27	397.32
Northwest	9.95	14.11	14.13	11.78	6.20	14.23		11.03	81.43	25.00	20.00	71.56	75.33	41.46	101.90		49.42	384.66
Southwest	12.43	10.63	11.26	13.87	18.20	15.84	30.41		112.65	16.95	7.70	26.65	41.74	32.47	69.61	29.18		224.30
Total	58.19	131.71	122.46	96.32	71.38	103.59	104.37	60.61	748.63	118.84	135.99	327.96	431.71	219.01	486.69	137.25	206.59	2064.05
	Share of bilateral TiCE in total interregional TiCE (%)																	
Northeast		2.25	2.56	0.70	0.74	1.32	1.42	1.03	10.02		1.29	3.20	2.30	1.22	3.82	0.92	1.21	13.96
North Municipalities	0.31		1.87	0.22	0.14	0.34	0.32	0.20	3.40	0.36		1.93	0.53	0.28	0.77	0.26	0.31	4.42
North Coast	1.39	6.42		1.20	0.66	1.86	1.73	0.51	13.77	1.51	2.64		3.36	1.67	5.57	1.51	1.62	17.88
East Coast	0.46	1.07	2.31		1.53	4.68	1.29	1.12	12.46	0.33	0.23	0.94		1.44	2.91	0.47	0.72	7.05
South Coast	0.45	0.56	0.89	1.15		1.62	1.16	1.70	7.53	0.57	0.24	0.72	1.44		2.20	0.72	2.05	7.93
Central	2.18	3.99	5.33	6.17	3.21		3.96	2.06	26.89	0.96	0.85	4.34	7.61	2.42		1.36	1.71	19.25
Northwest	1.33	1.89	1.89	1.57	0.83	1.90		1.47	10.88	1.21	0.97	3.47	3.65	2.01	4.94		2.39	18.64
Southwest	1.66	1.42	1.50	1.85	2.43	2.12	4.06		15.05	0.82	0.37	1.29	2.02	1.57	3.37	1.41		10.87
Total	7.77	17.59	16.36	12.87	9.54	13.84	13.94	8.10	100.00	5.76	6.59	15.89	20.92	10.61	23.58	6.65	10.01	100.00
	TiCE balance (million metric tons)																	
Northeast		14.48	8.79	1.81	2.19	-6.44	0.69	-4.71	16.82		19.08	34.91	40.65	13.62	59.04	-6.00	7.97	169.26
North Municipalities	-14.48		-34.06	-6.34	-3.19	-27.31	-11.73	-9.14	-106.25	-19.08		-14.77	6.18	0.73	-1.66	-14.66	-1.40	-44.66
North Coast	-8.79	34.06		-8.27	-1.70	-26.01	-1.19	-7.47	-19.38	-34.91	14.77		50.00	19.56	25.24	-40.36	6.86	41.17
East Coast	-1.81	6.34	8.27		2.86	-11.14	-2.14	-5.45	-3.08	-40.65	-6.18	-50.00		-0.09	-96.98	-65.54	-26.80	-286.24
South Coast	-2.19	3.19	1.70	-2.86		-11.87	2.51	-5.45	-14.98	-13.62	-0.73	-19.56	0.09		-4.51	-26.70	9.75	-55.28
Central	6.44	27.31	26.01	11.14	11.87		15.42	-0.44	97.75	-59.04	1.66	-25.24	96.98	4.51		-73.92	-34.34	-89.38
Northwest	-0.69	11.73	1.19	2.14	-2.51	-15.42		-19.38	-22.94	6.00	14.66	40.36	65.54	26.70	73.92		20.24	247.41
Southwest	4.71	9.14	7.47	5.45	5.45	0.44	19.38		52.05	-7.97	1.40	-6.86	26.80	-9.75	34.34	-20.24		17.71
Total	-16.82	106.25	19.38	3.08	14.98	-97.75	22.94	-52.05	0.00	-169.26	44.66	-41.17	286.24	55.28	89.38	-247.41	-17.71	0.00
	TiCE/TiVA (metric tons per 10-thousand Chinese yuan at constant price; base year: 2002)																	
Northeast		4.3	4.3	5.1	4.0	4.3	3.9	3.7	4.2		6.1	6.7	6.0	4.2	6.7	5.1	4.6	5.9
North Municipalities	2.8		2.3	4.2	2.4	3.3	2.9	2.1	2.5	1.9		1.5	2.2	1.7	1.6	1.6	1.4	1.6
North Coast	5.8	6.0		4.7	3.6	3.6	4.8	3.6	5.0	6.7	5.9		6.8	5.0	4.7	5.0	4.7	5.3
East Coast	2.4	2.7	2.2		2.3	2.6	2.3	1.9	2.4	2.7	2.9	2.9		2.4	2.8	2.5	2.4	2.7
South Coast	1.9	2.0	1.8	2.4		1.9	1.9	1.8	1.9	2.3	2.5	2.4	3.5		2.4	2.3	2.2	2.5
Central	7.0	7.3	4.5	5.0	4.9		5.7	4.2	5.3	6.1	5.9	6.3	5.3	4.4		5.3	4.6	5.3
Northwest	7.5	9.6	6.2	7.3	6.4	6.0		5.6	6.8	7.2	6.8	6.3	6.2	5.9	5.4		4.5	5.8
Southwest	6.9	6.8	4.3	6.7	4.8	4.9	5.8		5.5	6.1	6.0	5.8	6.4	3.3	5.4	4.9		5.1
Total	5.1	5.5	3.4	4.8	4.0	3.2	4.1	2.9	4.0	4.6	5.6	4.2	5.4	3.8	4.1	3.9	3.4	4.3

Figure 4 China's inter-regional trade in CO2 emissions



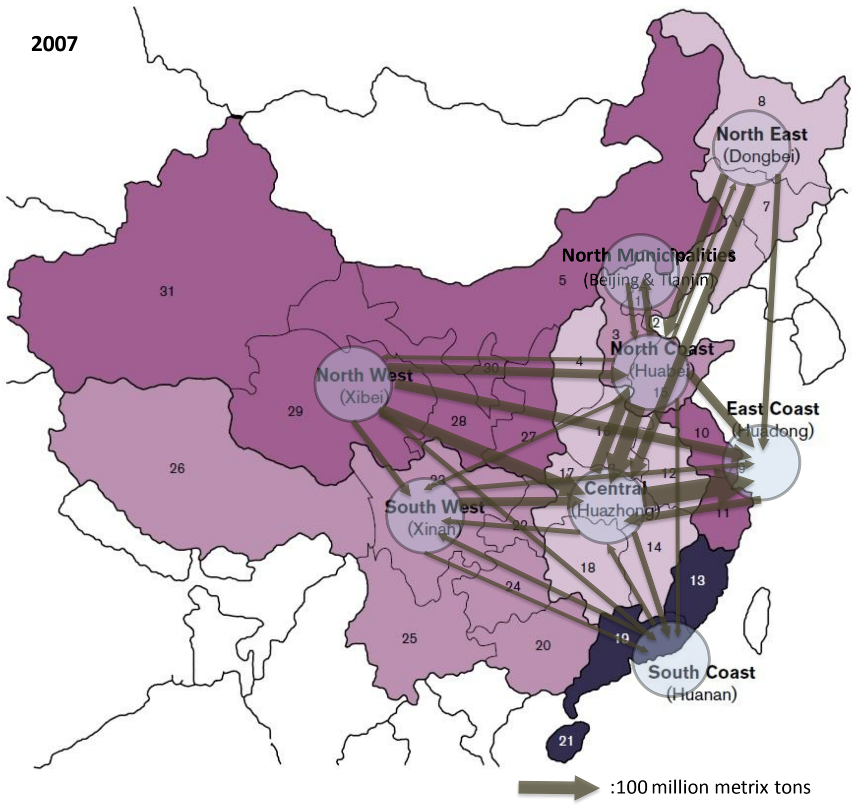


Table 7 Trans-regional CO2 emissions induce by regional consumption (production) of locally made products (1997-2007)

Trans-regional CO2 emissions induced by regional consumption of locally made final products for 2002 (unit: million metric tons)										
	Northeast	North Municipalities	North Coast	East Coast	South Coast	Central	Northwest	Southwest	Row sum	Gain potential
Northeast		10.52	13.30	4.31	3.24	7.25	7.04	4.92	50.58	0.8
North Municipalities	1.62		6.90	1.12	0.55	1.67	1.46	0.70	14.01	0.2
North Coast	8.42	35.47		7.29	3.03	10.59	10.38	2.50	77.68	1.2
East Coast	2.31	3.85	8.76		5.53	26.98	5.55	4.47	57.44	0.9
South Coast	2.47	2.49	3.79	6.32		7.98	5.89	8.05	36.97	0.6
Central	13.26	20.45	28.35	36.31	16.76		23.62	11.24	149.98	2.3
Northwest	7.95	8.82	9.39	9.27	4.28	11.01		7.18	57.89	0.9
Southwest	9.13	6.18	6.86	10.42	12.39	11.91	22.94		79.83	1.2
Column sum	45.15	87.78	77.34	75.02	45.78	77.39	76.86	39.06	524.38	
Give-out potential	0.7	1.3	1.2	1.1	0.7	1.2	1.2	0.6		
Trans-regional CO2 emissions induced by regional consumption of locally made final products for 2007 (unit: million metric tons)										
	Northeast	North Municipalities	North Coast	East Coast	South Coast	Central	Northwest	Southwest	Row sum	Gain potential
Northeast		15.87	41.35	33.83	12.32	23.88	7.07	11.15	145.47	1.0
North Municipalities	3.84		17.03	7.42	2.08	4.70	1.84	1.75	38.66	0.3
North Coast	21.80	45.51		59.82	19.52	57.44	17.61	15.36	237.06	1.6
East Coast	3.51	3.05	12.43		14.29	28.17	3.96	6.22	71.64	0.5
South Coast	5.45	3.09	8.89	25.29		18.54	5.49	17.91	84.66	0.6
Central	12.21	11.67	66.50	127.96	30.85		14.81	17.51	281.50	1.9
Northwest	15.82	12.28	43.03	56.77	21.24	34.98		21.57	205.70	1.4
Southwest	7.87	3.51	16.48	34.70	19.79	21.11	7.18		110.65	0.8
Column sum	70.49	94.99	205.71	345.80	120.09	188.83	57.97	91.47	1,175.35	
Give-out potential	0.5	0.6	1.4	2.4	0.8	1.3	0.4	0.6		
Growth rate of trans-regional CO2 emissions between 2002 and 2007 (unit: %)										
	Northeast	North Municipalities	North Coast	East Coast	South Coast	Central	Northwest	Southwest	Row sum	Gain potential
Northeast		51	211	685	280	229	0	127	188	28
North Municipalities	137		147	565	279	181	26	150	176	23
North Coast	159	28		721	544	443	70	514	205	36
East Coast	52	-21	42		158	4	-29	39	25	-44
South Coast	121	24	135	300		132	-7	122	129	2
Central	-8	-43	135	252	84		-37	56	88	-16
Northwest	99	39	358	513	396	218		201	255	59
Southwest	-14	-43	140	233	60	77	-69		39	-38
Column sum	56	8	166	361	162	144	-25	134	124	
Give-out potential	-30	-52	19	106	17	9	-66	4		

Table 8 Trans-regional CO2 emissions induced by regional consumption of final inflow products (1997-2007)

Trans-regional CO2 emissions induced by regional consumption of final inflow products for 2002 (unit: million metric tons)										
	Northeast	North Municipalities	North Coast	East Coast	South Coast	Central	Northwest	Southwest	Row sum	Gain potential
Northeast		6.29	5.90	0.95	2.29	2.61	3.60	2.80	24.43	0.9
North Municipalities	0.71		7.12	0.52	0.49	0.90	0.92	0.79	11.45	0.4
North Coast	1.98	12.61		1.72	1.90	3.34	2.55	1.30	25.40	0.9
East Coast	1.14	4.12	8.53		5.94	8.04	4.09	3.95	35.80	1.3
South Coast	0.86	1.74	2.84	2.30		4.17	2.82	4.70	19.43	0.7
Central	3.04	9.43	11.58	9.85	7.26		6.04	4.16	51.36	1.8
Northwest	2.00	5.29	4.74	2.51	1.92	3.22		3.85	23.54	0.8
Southwest	3.30	4.45	4.41	3.46	5.81	3.93	7.48		32.83	1.2
Column sum	13.03	43.93	45.12	21.31	25.60	26.20	27.51	21.54	224.24	
Give-out potential	0.5	1.6	1.6	0.8	0.9	0.9	1.0	0.8		
Trans-regional CO2 emissions induced by regional consumption of final inflow products for 2007 (unit: million metric tons)										
	Northeast	North Municipalities	North Coast	East Coast	South Coast	Central	Northwest	Southwest	Row sum	Gain potential
Northeast		10.66	24.70	13.61	12.96	55.00	11.93	13.77	142.64	1.3
North Municipalities	3.61		22.74	3.52	3.60	11.16	3.50	4.55	52.67	0.5
North Coast	9.35	9.03		9.51	14.98	57.46	13.59	18.16	132.06	1.2
East Coast	3.28	1.71	6.89		15.42	31.98	5.83	8.72	73.84	0.7
South Coast	6.21	1.86	6.05	4.51		26.85	9.27	24.32	79.07	0.7
Central	7.64	5.85	23.17	29.17	19.06		13.18	17.76	115.81	1.0
Northwest	9.18	7.72	28.52	18.56	20.21	66.92		27.85	178.96	1.6
Southwest	9.08	4.19	10.17	7.04	12.68	48.49	21.99		113.64	1.0
Column sum	48.35	41.01	122.24	85.92	98.92	297.86	79.28	115.12	888.70	
Give-out potential	0.4	0.4	1.1	0.8	0.9	2.7	0.7	1.0		
Growth rate of trans-regional CO2 emissions between 2002 and 2007 (unit: %)										
	Northeast	North Municipalities	North Coast	East Coast	South Coast	Central	Northwest	Southwest	Row sum	Gain potential
Northeast		69	319	1,337	467	2,007	231	392	484	47
North Municipalities	409		219	577	640	1,145	279	475	360	16
North Coast	371	-28		452	688	1,621	432	1,301	420	31
East Coast	189	-58	-19		160	298	42	121	106	-48
South Coast	619	7	113	96		545	228	417	307	3
Central	151	-38	100	196	163		118	327	125	-43
Northwest	358	46	501	639	954	1,978		623	660	92
Southwest	175	-6	131	104	118	1,134	194		246	-13
Column sum	271	-7	171	303	286	1,037	188	434	296	
Give-out potential	-6	-76	-32	2	-3	187	-27	35		

Figure 5 Give-out and gain potentials of trans-regional trade in CO2 emissions in terms of final demand on locally produced products

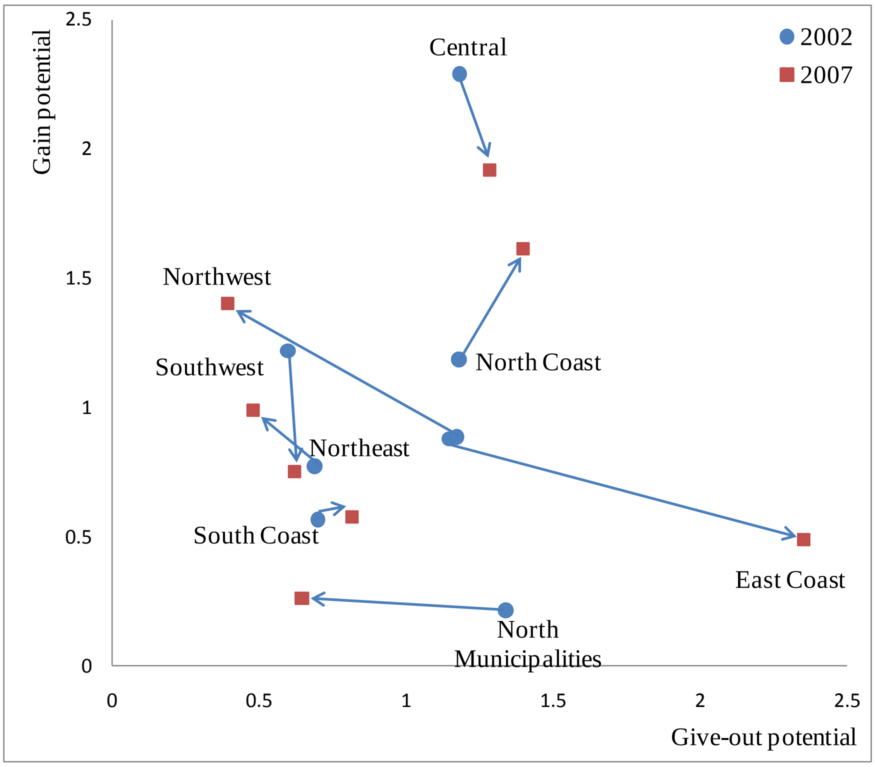


Figure 6 Give-out and gain potentials of trans-regional trade in CO2 emissions in terms of final demand on inflow products

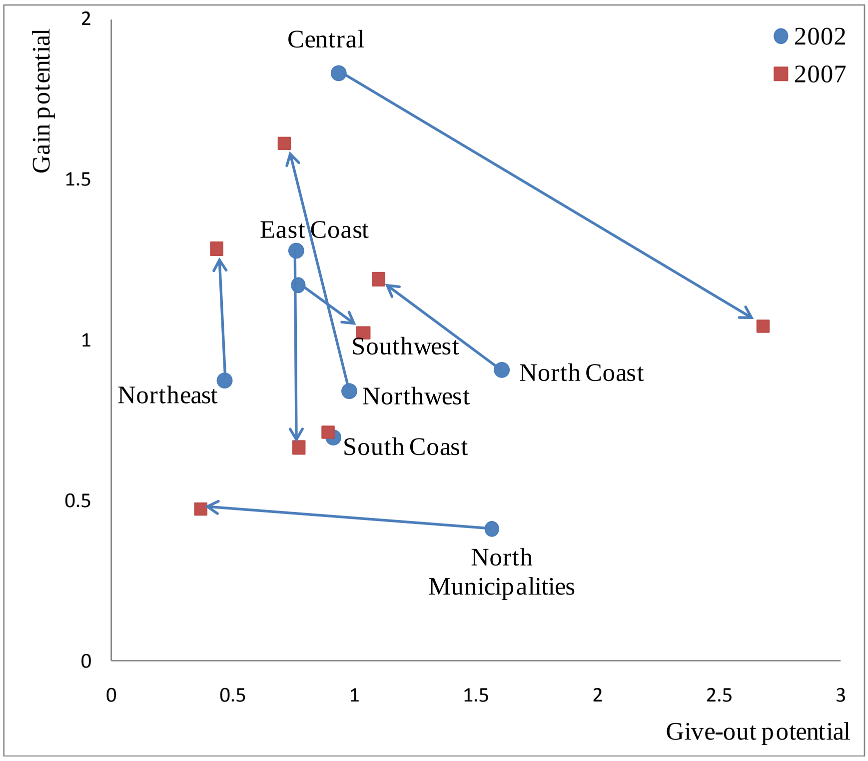


Table 9 TiCE based domestic revealed comparative advantage indicator and its changing pattern between 1997 and 2007

		Agriculture	Mining and quarrying	Food products and tobacco	Textile and garment	Wood products and furniture	Pulp, paper, and printing	Chemical	Non-metallic mineral products	Metal products	General machinary	Transport equipment	Electric applicances and electronics	Other manufacturing products	Electricity, gas, and water supply	Construction	Trade and transportation	Other services
2002	Northeast	1.02	1.04	0.87	0.09	1.24	0.35	1.38	0.33	1.33	1.07	1.59	0.92	0.35	0.91	0.36	1.16	1.81
	North Municipalities	0.33	0.57	0.78	0.62	1.11	0.55	1.05	0.53	1.34	1.55	1.84	4.30	1.28	0.79	2.33	1.45	5.45
	North Coast	1.11	0.54	1.62	2.05	1.20	2.21	0.84	1.88	0.89	1.33	0.39	0.91	1.46	1.01	0.77	0.06	0.49
	East Coast	0.89	0.13	0.40	2.65	0.67	0.66	1.33	0.64	0.74	1.74	0.72	1.59	0.87	1.11	1.62	1.94	0.95
	South Coast	0.89	0.12	3.55	1.77	2.50	2.79	0.65	0.83	0.73	0.86	1.85	2.30	3.39	1.07	0.15	2.23	1.33
	Central	1.15	1.17	0.58	0.64	1.00	0.67	0.97	1.08	1.10	0.75	1.19	0.45	0.47	0.99	0.18	0.79	0.53
	Northwest	0.99	1.80	0.87	0.26	0.27	1.02	0.88	0.65	0.57	0.75	0.42	0.97	0.58	1.19	3.94	0.74	0.99
	Southwest	0.93	1.78	0.63	0.15	0.69	0.39	0.92	1.23	1.29	0.61	0.86	0.25	1.10	0.86	0.58	0.82	0.65
2007	Northeast	1.35	1.18	1.35	0.04	1.54	0.31	1.40	0.55	0.72	0.86	2.45	0.27	1.43	1.24	1.11	0.54	0.46
	North Municipalities	0.77	0.43	1.33	0.25	0.21	0.32	1.20	0.32	0.85	1.20	2.33	0.32	3.00	0.83	0.77	1.97	8.50
	North Coast	0.87	0.45	0.83	1.14	1.91	1.04	0.82	1.18	1.81	1.05	0.56	1.21	0.62	0.74	0.01	0.67	0.61
	East Coast	0.42	0.31	0.26	1.81	0.43	1.44	1.57	0.73	0.81	2.59	1.07	1.78	0.77	1.05	0.71	1.74	0.84
	South Coast	0.43	0.17	0.18	6.89	1.66	3.78	0.46	1.48	0.71	2.62	0.27	3.72	2.89	0.97	0.14	1.32	0.92
	Central	0.94	1.49	0.86	0.29	0.89	1.07	1.28	1.39	1.14	0.86	0.99	0.99	0.97	0.83	0.50	0.84	0.34
	Northwest	1.23	1.71	1.31	0.18	0.19	0.44	0.77	0.63	0.48	0.22	0.29	0.54	0.21	1.31	2.05	1.05	1.14
	Southwest	1.37	0.88	1.49	0.16	0.60	0.61	0.63	1.32	1.06	0.38	1.03	0.19	0.44	0.95	2.47	1.24	0.37

(dark shading): first rank (light shading): second rank

Figure 7 Give-out potential of induced CO2 emissions by regional exports

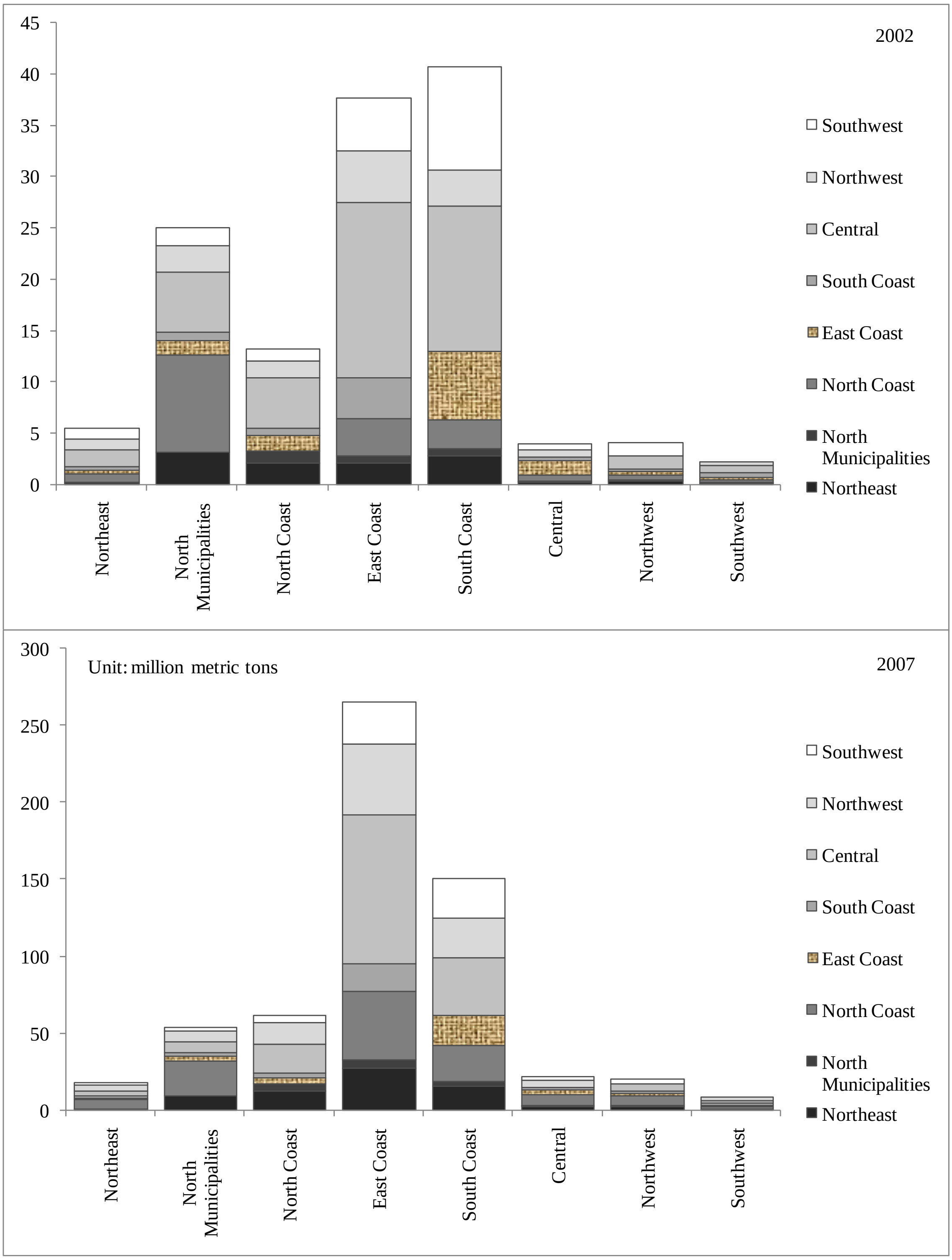
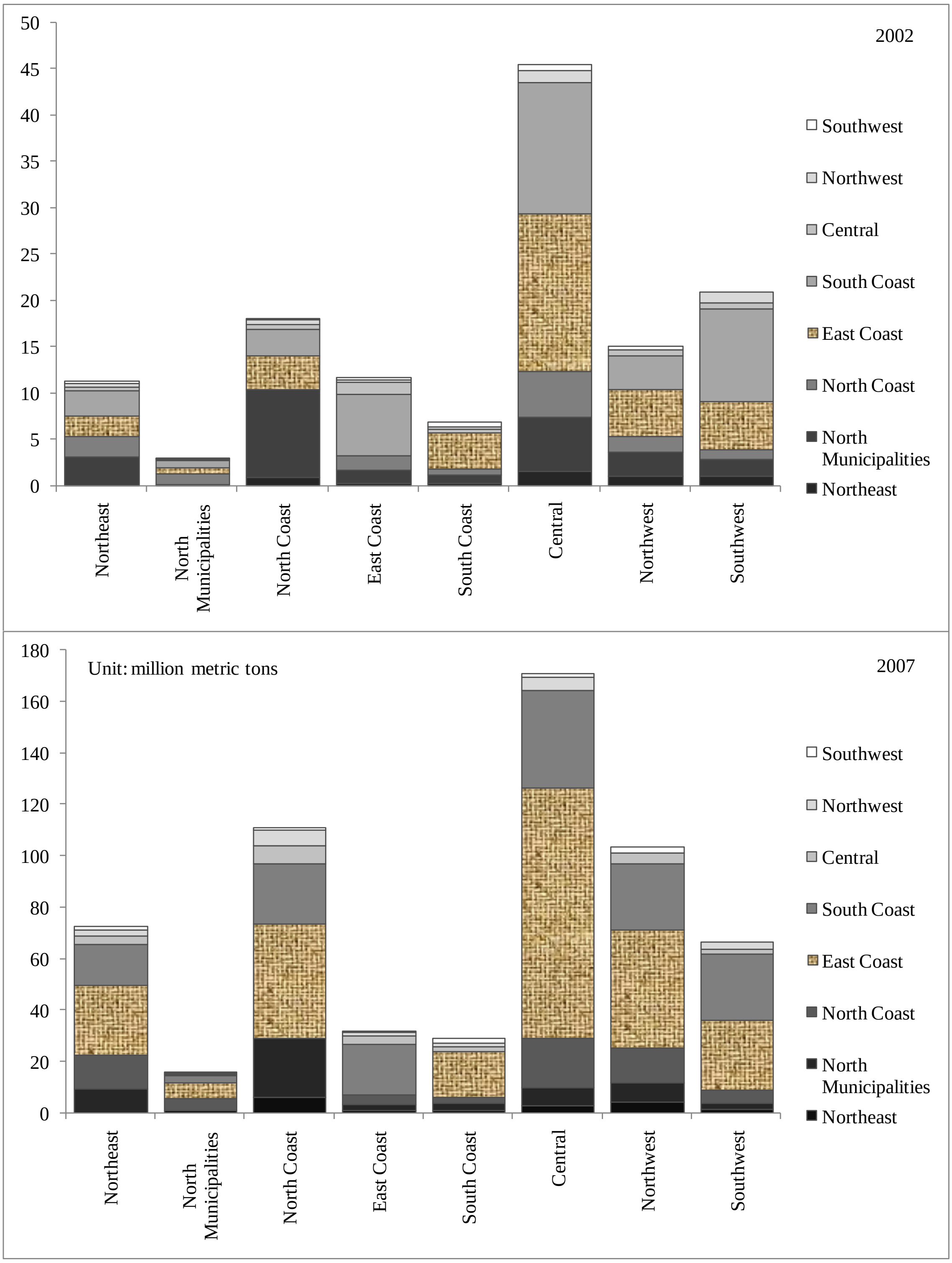


Figure 8 Gain potential of induced CO2 emissions by regional exports



Appendix 1 Region classification

Eight Regions	**31 provincial level divisions**
Northeast	Liaoning, Jilin ,Heilongjiang
North Municipalitis	Beijing, Tianjin
North Coast	Hebei, Shandong
East Coast	Shanghai, Jiangsu, Zhejiang
South Coast	Fujian, Guangdong, Hainan
Central	Shanxi, Anhui, Jiangxi, Henan, Hubei, Hunan
Northwest	Inner Mongolia, Shaanxi, Gansu, Qinghai, Ningxia, Xinjiang
Southwest	Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Tibet