Incorporating consumption-based emissions accounting into climate policy in China: Provincial target setting and ETS baseline allocations

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Summary

An important policy question in China is how to equitably allocate the responsibility for reducing carbon emissions. China has already introduced provincial targets to achieve a national carbon intensity reduction of 17% in its Twelfth Five-Year Plan, and the design of a cap-and-trade system is currently under discussion. Using a computable general equilibrium model with energy system detail, we assess alternative criteria—production emissions, consumption emissions, and a shared production and consumption metric—for allocating the national CO_2 intensity target across provinces, and compare them to the existing politically-negotiated targets. We show how economic cost can be lowered and equity goals addressed by employing a permit trading mechanism and how equity goals can be achieved through the choice of index used to determine the initial allocation.

Adjusting the provincial targets on a consumption basis increases the emissions-reduction burden for the eastern provinces by about 60%, while alleviating the burden for the central and western provinces by about 50% each. This adjustment makes meeting policy targets more expensive—the CGE analysis indicates that this adjustment could double China's national welfare loss compared to the homogenous and politically-based distribution of reduction targets. The welfare losses for the eastern provinces increase by a factor of four, while providing little relief for the central and western provinces. A shared-responsibility approach that balances production-based and consumption-based emissions responsibilities alleviates those unbalancing effects and lead to a more equal distribution of economic burden among China's provinces. An emissions-trading system (ETS) that achieves the same reduction and applies various criteria to determine the initial allocation lowers the cost relative to all corresponding intensity target scenarios while still addressing equity concerns. Allocating emissions allowances based on a consumption-based approach results in a greater alleviation of regional welfare impacts and a more equal distribution of economic burden than the regional shared-responsibility scenario. This analysis argues in favor of developing a Chinese ETS and of scaling up efforts to measure, report, and verify emissions, which would in turn allow for a differentiated allocation of allowances similar to that analyzed in this study.

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1. Introduction

China has surpassed the United States in 2007 to become the world's largest emitter of carbon dioxide (CO_2) (IEA, 2007; MNP, 2007). This has increased international pressure on China to adopt stringent emissions-reduction commitments. During the 15th Conference of the Parties to the United Nations Framework Convention on Climate Change (UNFCCC) in Copenhagen, China has pledged to reduce its carbon intensity, i.e., CO_2 emissions per unit of gross domestic product (GDP) by 40% to 45% from 2005 levels by 2020 (NRDC, 2009). China's 12th Five-Year Plan (FYP) for economic and social development which runs from 2011 to 2015 has integrated part of this commitment into national policy. For the first time, it introduced an explicit target to reduce the national carbon intensity by 17% during the years from 2011 to 2015 (State Council of China, 2012).[1]

Due to the large regional disparities that exist within China, the ease of meeting the national emissions-intensity target will depend critically on its regional implementation. Within China there are pronounced differences between the developed eastern-coastal provinces and the less developed central and western provinces (Keidel, 2007; Feng et al., 2009). For example, the per-capita GDP between the coastal municipality of Shanghai and the southwest province of Guizhou differs by a factor of ten (NBS China, 2008). On aggregate, the per-capita GDP in the inland regions is less than half of that in the coastal regions (Fan et al., 2009). Those disparities lead to large differences in regional CO_2 emissions and emissions intensities, with the eastern-coastal provinces having relatively higher emissions but lower emissions intensities than the central and western provinces (Meng et al., 2011; Feng et al., 2012; Liu et al., 2012).

Allocating a national target homogenously to each province can further promote regional disparities and result in excess cost burden for some provinces. For the 12th FYP the Chinese State Council has therefore differentiated the national carbon-intensity target, ranging from 10% carbon-intensity reductions for some western provinces (Qinghai and Tibet) to 19.5% for the eastern-coastal province of Guangdong. While little is known about the explicit allocation scheme that was followed by the State Council, researchers have argued that a more transparent and science-based methodology should guide the setting of future energy and carbon targets on the provincial level (Ohshita et al., 2011).[2] This study contributes to this discussion.

1.1 Provincial target-setting approaches

[1] Prior to this, the Eleventh Five-Year Plan was focused on energy intensity (and did not set a target for carbon intensity). It included a target to reduce energy intensity by 20% nationwide (96% of which has been achieved). The target was not formally allocated to provinces but comprised of pledges made by each province (World Bank, 2009).

[2] See also, e.g., http://www.chinafaqs.org/blog-posts/targets-provinces-energy-intensity-12th-five-year-plan [accessed 10/23/2012] and http://blogs.worldwatch.org/can-china-do-a-better-job-delegating-its-2015-energy-and-emissions-targets/ [accessed 10/23/2012].

Previous analyses have proposed several aggregate indices for informing the regional target allocation of carbon-intensity reductions in China. For example, Wei et al. (2011) have constructed an abatement capacity index based on weighted equity and efficiency indexes. Based on time series data from 1995-2007, the equity index includes per-capita CO_2 emissions and per-capita GDP, while the efficiency index includes regional emissions intensity and marginal-abatement costs. Yi et al. (2011) have constructed an aggregate index for informing the carbon intensity allocation in 2020. Their index is based on per-capita GDP (to indicate the capacity for emissions reduction), accumulated fossil-fuel related CO_2 emissions (to indicate the responsibility for emissions reduction), and energy consumption per unit of industrial value added (to indicate the potential for emissions reduction). Finally, Ohshita et al. (2011) combine top-down national target projections and bottom-up provincial and sectoral projections to suggest an allocation for the additional national energy target of 20% energy intensity improvements during the 12th FYP among Chinese provinces.

1.2 Accounting for regional emissions transfers in provincial target setting

While the target allocation methods described above aim to address equity issues by including per-capita indices of emissions and GDP, they do not account for the potential impact that interregional trade can have on the stringency and distributional aspects of regional emissions targets. Studies on the international level have found that trade can make compliance with emissions-reduction targets easier for regions that import emissions-intensive products without producing them and harder for those regions that are exporting such products (Wyckoff and Roop, 1994; Munksgaard and Pedersen, 2001). Industrialized countries, in particular, have been found to be net importers of emissions embodied in trade, while developing countries are found to be net exporters (Peters and Hertwich, 2008). With respect to China, Davis and Caldeira (2010) have estimated that 22.5% of the emissions produced in China in 2004 were exported, on net, to consumers primarily in developed countries (see also Shui and Harriss, 2006; Wang and Watson, 2008; Lin and Sun, 2010).

The issue of emissions transfers is mirrored and amplified on the regional level due to China's uneven regional distribution of production and consumption activities. CO_2 emissions embodied in interprovincial trade have accounted for as much as 64% of China's total CO_2 emissions in 2002, exceeding those embodied in China's international exports by a factor of three (Guo et al., 2012). On net, emissions transfers occur from the eastern-coastal provinces to the central and western provinces (Liang et al., 2007; Guo et al., 2012; Meng et al., 2011), primarily through the trade in energy-intensive products, such as steel, but also through energy transfers as most coal resources are located in the western and central provinces. Thus, the eastern-coastal provinces outsource part of their emissions by importing energy-intensive and energy-related goods, without being held accountable for the emissions embodied in those imports. In turn, the central and western provinces experience a greater burden as they increase their emissions to produce for interregional export. The interregional emissions transfers therefore distort the regional allocation of China's emissions-intensity target and make it less equitable.

Consumption-based emissions inventories have been proposed to highlight the trade-induced separation of production from consumption and the associated distributional consequences of emissions transfers (Peters and Hertwich, 2008). A consumption-based inventory includes the emissions embodied in imports and subtracts those embodied in exports (Munksgaard and Pedersen, 2001; Munksgaard et al., 2005). Compared to the polluter-pays principle of the production-based approach, it stresses the emissions responsibility of the beneficiary, i.e., the consumer of the good, for the emissions generated in the production process. For the Chinese context, Guo et al. (2012) have constructed a consumption-based emissions inventory for China's provinces and calculated consumption-based regional emissions intensities.[3]

1.3 Advantages and disadvantages of consumption-based approaches

The main problem of consumption-based approaches is that they extend the reach of climate policies across regional borders, which makes them incompatible with regional sovereignty. Although adjusting emissions targets for regional emissions transfers does not necessarily violate national or regional sovereignty, the adjusted targets may overburden highly emissions exporting regions if those regions are not given access to abatement possibilities outside their jurisdictions. The Clean Development Mechanism (CDM) under the Kyoto Protocol may be seen as such an instrument which is compatible with the territorial extent of consumption-based approaches on the international level. Carbon tariffs or, more generally, border carbon adjustments are another instrument that goes into that direction, albeit with potentially detrimental economic and distributional impacts (see, e.g., Springmann, 2012, 2013).

While those instruments could, in principle, be implemented on the regional level, i.e., within a common national jurisdiction, there are other instruments, such as differentiated emissions allocation within an emissions-trading system (ETS), that may be better suited on that level and be more in line with the development trajectories of national and international climate policies. The Chinese government has indicated in its 12th FYP the intent to establish a national carbon trading system by 2015 (Han et al., 2012). Zhang et al. (2012) have demonstrated in a general-equilibrium framework that a national emissions-intensity target, together with emissions trading, reduces national welfare loss relative to implementing regional targets that do not allow for emissions trading.

Efficiency and equity objectives can be separated in an ETS, since an ETS attains cost-efficiency in abatement (due to incentives to reduce emissions where it is cheapest) irrespective of the initial allocation of emission permits (Coase, 1960; Rose and Tietenberg, 1993). Wei and Rose (2009) have illustrated the potential of addressing efficiency and equity objectives within a Chinese ETS by simulating an interregional tradable permits system for energy-conservation quotas in which the quota allocation was determined by a range of

[3] Their results indicate higher emissions intensities for the emissions-exporting eastern-coastal provinces and lower emissions intensities for the emissions-importing central and western provinces. The analysis is based on data from the year 2002. As a part of this study, we recalculate the emissions embodied in China's interregional trade using an updated dataset for the year 2007.

different equity criteria. However, they did not consider an equity criterion which indicates the consumption responsibilities for the emissions embodied in trade.

1.4 Contributions of this study

Consumption-based emissions inventories have been used regularly for indicating the distributional consequences of emissions transfers (see, e.g., Wiedmann et al., 2007). However, there is little research on how to integrate a consumption-based approach in policy-making and what the potential impacts would be. This study aims to fill this gap. First, it derives trade-adjusted emissions-intensity targets that can be implemented in a conventional production-based system. In correcting for emissions transfers, this policy implementation highlights the magnitude of emissions-intensity reduction that would be necessary if provinces were held responsible for the emissions driven by their consumption demand. We simulate the effects of such a target allocation by employing an interregional computable-general-equilibrium (CGE) model of the Chinese economy which provides a comprehensive representation of regional market interactions through price and income-responsive supply and demand reactions (see Zhang et al., 2012).

The second application of this study is to allocate the regional baseline allowances of a Chinese ETS with a consumption-based approach and to simulate the economic and distributional effects of this allocation method. Similarly to the first application, we use an interregional CGE model of the Chinese economy and compare the economic and distributional effects of both applications with each other, i.e., strictly regional targets informed by a consumption-based approach with an ETS whose baseline allocation is informed by a consumption-based approach. In each application, we pursue detailed comparisons with a range of other target-allocation schemes, such as implementing homogenous production-based targets, targets informed by a shared responsibility between consumers and producers, and of implementing the politically negotiated targets that have been assigned under the 12th FYP are pursued.

The remainder of this manuscript is structured as follows. Section 2 outlines a general method to derive trade-adjusted emissions-intensity targets and baseline allocations. A succinct description of the CGE model used in this study and of the model scenarios implemented are provided in Sections 3 and 4. Section 5 presents the results of both applications, and Section 6 concludes.

2. Trade-adjusting emissions-intensity targets

Consumption-based inventories have been used to highlight the importance of emissions embodied in trade and the associated distributional consequences that emissions transfers have on national and international climate policies (Wyckoff and Roop, 1994; Munksgaard and Pedersen, 2001; Peters and Hertwich, 2008). In the following, we derive trade-adjusted emissions-intensity targets which are based on a consumption-based approach, but which can be implemented in a production-based system to account for interregional emissions transfers. Due to our application to China, we concentrate on emissions-intensity targets. However, the derivations can be easily adopted to also adjust absolute emissions targets for consumption responsibilities.

2.1. Production-based emissions intensities

In a production-based system, a region's emissions intensity (EI_r^{PAP}) is defined as the ratio of territorial emissions (e_r^{PAP}) to unit of economic activity, usually taken to be GDP:

$$EI_r^{PAP} = \frac{e_r^{PAP}}{GDP_r} \tag{1}$$

Mandates for reductions in emissions intensity are commonly expressed in percentage reductions of baseline emissions intensities ($r_{EI,r}^{PAP}$). The corresponding absolute emissions-intensity targets are obtained by subtracting the share of percentage emissions-intensity reductions from the baseline emissions intensities:

$$t_{EI,r}^{PAP} = \left(1 - r_{EI,r}^{PAP}\right) EI_r^{PAP} \tag{2}$$

The total emissions-intensity target (T_{EI}^{PAP}) is given by the GDP-weighted average of the regional emissions-intensity targets:

$$T_{EI}^{PAP} = \frac{\sum_r t_{EI,r}^{PAP} GDP_r}{\sum_r GDP_r} = \frac{\sum_r \left(1 - r_{EI,r}^{PAP}\right) e_r^{PAP}}{GDP} \tag{3}$$

where GDP denotes total GDP summed over all regions.

2.2. Consumption-based emissions intensities

Consumption-based emissions inventories add to the production-based emissions those emissions that are embodied in imports (e_r^{IM}), but subtract those emissions that are embodied in exports (e_r^{EX}):

$$e_r^{CAP} = e_r^{PAP} + e_r^{IM} - e_r^{EX} = e_r^{PAP} + B_r \tag{4}$$

where $B_r (= e_r^{IM} - e_r^{EX})$ denotes the balance of emissions embodied in trade (see, e.g., Peters and Hertwich, 2008), also referred to as emissions transfer (Peters et al., 2011).

Consumption-based emissions intensities (EI_r^{CAP}) can be calculated by adding the ratio of emissions transfers to GDP to the production-based emissions intensities:

$$EI_r^{CAP} = \frac{e_r^{PAP} + B_r}{GDP_r} \quad (5)$$

Regions which are net importers of embodied emissions (with positive B_r) have higher emissions intensities under the consumption-based approach, while the emissions intensities of net exporting regions (with negative B_r) are lower compared to those in the production-based approach.

2.3. Trade-adjusted emissions-intensity targets

The study's objective is to account for consumption responsibilities in a production-based system. We therefore calculate adjusted emissions-intensity reduction targets, while continuing to use the production-based emissions intensities as baselines. There are several ways of adjusting the production-based emissions-intensity targets to account for consumption responsibilities. However, not all possibilities conserve the total emissions-intensity target defined in the production-based approach.[4] A consistent method is to subtract the ratio of emissions transfers to GDP from the production-based emissions-intensity targets:

$$t_{EI,r}^{CAP} = \left(1 - r_{EI,r}^{PAP}\right) EI_r^{PAP} - \frac{B_r}{GDP_r} \quad (6)$$

The intuition is that regions which are net imports of embodied emissions (i.e., with positive B_r) have to bear stricter (i.e., lower) emissions-intensity targets, while the emissions-intensity targets of net exporters of embodied emissions is relaxed.

The associated percentage emissions-intensity reductions that would need to be applied to the production-based emissions-intensity baseline can be obtained by bringing the consumption-based emissions-intensity target into the form: $t_{EI,r}^{CAP} = \left(1 - r_{EI,r}^{CAP}\right) EI_r^{PAP}$. This yields the trade-adjusted percentage emissions-intensity reductions as:

$$r_{EI,r}^{CAP} = r_{EI,r}^{PAP} + \frac{B_r}{GDP_r \, EI_r^{PAP}} = r_{EI,r}^{PAP} + \frac{B_r}{e_r^{PAP}} \quad (7)$$

[4] For example, one could argue that the emissions-intensity targets should not be adjusted by all of a region's emissions transfers, but only by some proportion (e.g., by the regional percentage emissions-reduction target $r_{EI,r}^{PAP}$, such that $t_{EI,r}^{CAP2} = \left(1 - r_{EI,r}^{PAP}\right) EI_r^{PAP} - r_{EI,r}^{PAP} \frac{B_r}{GDP_r}$). Similarly, one could argue that emissions transfers should be normalized by the GDP of the emissions-exporting regions ($t_{EI,r}^{CAP3} = \left(1 - r_{EI,r}^{PAP}\right) EI_r^{PAP} - \sum_s \frac{B_{s,r}}{GDP_s}$). While those approaches might have some intuitive appeal, they do not preserve the total emissions-intensity target as, unlike in Eq. (8), the adjustments to the production-based emissions-intensity targets do not sum to zero.

Regions with net imports of embodied emissions would be subjected to greater percentage emissions-intensity reductions, while the reductions of regions which are net exporters of embodied emissions would be lowered.

The method for adjusting regional EI-targets for emissions transfers as described above preserves the total emissions-intensity target given by the GDP-weighted average of the regional emissions-intensity targets:

$$T_{EI}^{CAP} = \frac{\sum_r t_{EI,r}^{CAP} GDP_r}{\sum_r GDP_r} = \frac{\sum_r \left(1 - r_{EI,r}^{PAP}\right) e_r^{PAP} - \sum_r B_r}{GDP} = T_{EI}^{PAP} \quad (8)$$

where it was used that the sum of all emissions transfers is zero, since one country's imports is another country's exports: $\sum_r B_r = \sum_r e_r^{IM} - \sum_r e_r^{EX} = 0$.

While the total emissions-intensity target is conserved in the static framework described above, it can be expected that general-equilibrium effects, especially feedbacks on regional GDP levels, can distort the conservation of that target.[5]

In our application, applying a consumption-based approach to regulate emissions-intensity reductions of Chinese provinces results in emissions-intensity targets that would allow some provinces to increase their emissions. Since this would set incentives inconsistent with the overall reduction goal, we set the targets of those provinces to their baseline levels. We redistribute the spare allowances created to keep the total emissions-intensity target fixed.

The total absolute emissions to be redistributed are given by:

$$T^{red} = \sum_r \left(t_{EI,r}^{old} - t_{EI,r}^{new}\right) GDP_r = \sum_r \left(r_{EI,r}^{new} - r_{EI,r}^{old}\right) e_r = -\sum_r r_{EI,r}^{old} e_r \quad (9)$$

where it was used that the adjusted (new) emissions-intensity targets are set to baseline levels, i.e., $r_{EI,r}^{new} = 0$.[6]

Redistributing the emissions allowances among the remaining regions (n_{adj}) in proportion to their GDP yields adjusted emissions-intensity targets for those regions, and bringing the adjusted emission-intensity targets into the form $t_{EI,r}^{adj} = \left(1 - r_{EI,r}^{adj}\right) EI_r^{PAP}$ yields the adjusted emissions reductions:

[5] In a general-equilibrium framework it does not hold anymore that baseline emissions can be recuperated from emissions intensities by multiplication with regional GDP levels, because those GDP levels have changed. However, the numerical analysis conducted in this study indicate that the deviations from the total emissions-intensity target amount to less than 2.5% for this study' model application.

[6] The total emissions to be redistributed, T^{red}, are positive because $r_{EI,r}^{old}$ are negative reductions (i.e., increases) in the provinces whose emissions-reduction targets are to be adjusted.

$$t_{EI,r}^{adj} = \left(1 - r_{EI,r}^{CAP}\right) EI_r^{PAP} + \frac{T^{red}}{n_{adj} GDP_r} \quad (10)$$

$$r_{EI,r}^{adj} = r_{EI,r}^{CAP} - \frac{T^{red}}{n_{adj} e_r} \quad (11)$$

Thus, redistributing the spare allowances of those regions which would otherwise increase their emissions intensities relaxes the reduction targets of the remaining regions in (inverse) proportion to the remaining regions' emissions.

2.6. Shared responsibility for emission-intensity reductions

The production-based accounting system stresses the emissions responsibility of the producer, while the consumption-based system stresses that of the consumer. It has frequently been argued that both those conceptions of responsibility represent extreme views and that a shared-responsibility approach may be closer to the distributional impacts of emissions generation and economic activity (Bastianoni et al., 2004; Gallego and Lenzen, 2005; Lenzen et al., 2007).[7]

Allocating shared responsibilities along a good's value chain is sensitive to sectoral aggregation (Lenzen et al., 2007). However, allocating emissions-intensity targets based on two accounting principles with the same total emissions-intensity target is straightforward. We define the shared emissions-intensity target as a proportional split between the two intensity targets:

$$t_{EI,r}^{SHR} = \frac{1}{2} t_{EI,r}^{PAP} + \frac{1}{2} t_{EI,r}^{CAP} \quad (12)$$

The associated percentage reductions can be obtained by calculating $t_{EI,r}^{SHR}$ with the equation above, imposing the standard form $t_{EI,r}^{SHR} = \left(1 - r_{EI,r}^{SHR}\right) EI_r^{PAP}$, and solving for $r_{EI,r}^{SHR}$:

$$r_{EI,r}^{SHR} = \frac{1}{2}\left(r_{EI,r}^{PAP} + r_{EI,r}^{CAP}\right) \quad (13)$$

Thus, the percentage reduction targets under shared responsibility are given by a simple average between production-based and consumption-based reduction targets.

[7] For example, the consumer of a good gains from its consumption, while the producer gains from its production and sale. Similarly on the regional level, standard trade theory knows many cases in which each trading partner gains. Producing for export raises one region's GDP, while importing products increases the varieties on offer and may reduce prices for consumers who then increase consumption.

While there are several ways of accounting for shared responsibility between consumers and producers for allocating emissions-reduction burden[8], the benefit of the method outlined above is that it illustrates how two potentially independent indicators for emissions-intensity reductions can be combined. In particular Eq. (12) can be generalized to combine different indicators which inform emissions-intensity targets into an aggregate reduction index. Indicators other than the emissions-based ones used in this study may include economic ones, such as per-capita GDP, or temporal ones, such as historical emissions (Yi et al., 2011; Wei et al., 2011). The general form of a composite indicator is then:

$$t_{EI,r}^{AGG} = \frac{1}{n_{agg}} \sum_i t_{EI,r}^{i} \; ; \quad r_{EI,r}^{AGG} = \frac{1}{n_{agg}} \sum_i r_{EI,r}^{i} \tag{14}$$

where n_{agg} denotes the number of indicators to be aggregated.

3. Model description

This study utilizes an energy-economic model with regional detail for the Chinese economy. A detailed model description is provided by Zhang et al. (2012). In short, the model is a computable general equilibrium model based on optimizing behavior of economic agents. Consumers maximize welfare subject to budget constraints and producers combine intermediate inputs and primary factors at least cost to produce output. Energy resources are included as primary factors whose use is associated with the emission of carbon dioxide (CO_2). The model is formulated as a mixed complementarity problem (MCP) (Mathiesen, 1985; Rutherford, 1995) in which zero-profit and market-clearance conditions determine activity levels and prices.[9]

3.1. Model structure

The production of energy and other goods is described by nested constant-elasticity-of-substitution (CES) production functions which specify the input composition and substitution possibilities between inputs (see Figure 1). Inputs into production include labor, capital, natural resources (coal, natural gas, crude oil, and land), and intermediate inputs. For all non-energy goods, the CES production functions are arranged in four levels. The top-level nest combines an aggregate of capital, labor, and energy inputs (KLE) with material inputs (M); the second-level nest combines energy inputs (E) with a value-added composite of capital and labor inputs (VA) in the KLE-nest; the third-level nest captures the substitution possibilities

[8] For example, one could define shared-responsibility emission-intensity target by trade-adjusting the production-based target by half of a region's emissions transfers, i.e., $t_{EI,r}^{SHR} = \left(1 - r_{EI,r}^{PAP}\right) EI_r^{PAP} - \frac{1}{2}\frac{B_r}{GDP_r}$. This method also leads to a consistent allocation of emissions-reduction burden in that is preserved the total emissions-intensity target.

[9] The model is formulated in the mathematical programming system MPSGE (Rutherford, 1999), a subsystem of GAMS, and solved by using PATH (Dirkse and Ferris, 1995).

between electricity (ELE) and final-energy inputs (FE) composed, in the fourth-level nest, of coal (COL), natural gas (GAS), gas manufacture and distribution (GDT), crude oil (CRU), and refined oil products (OIL).

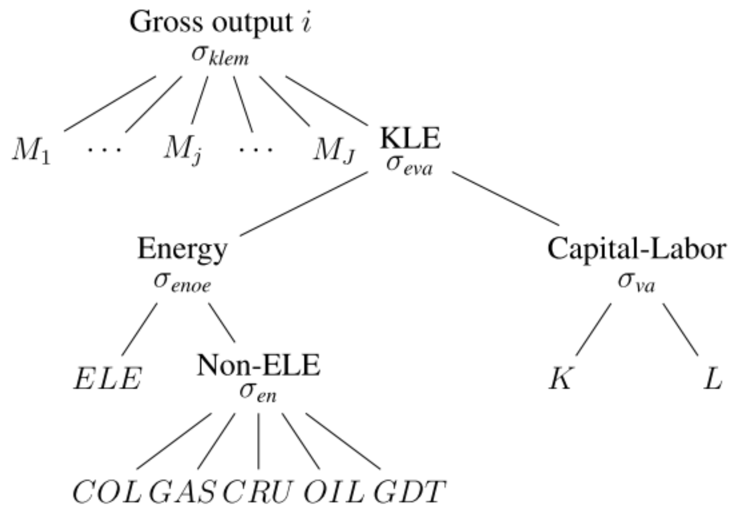

Figure 1. Nesting structure of CES production functions for non-energy goods.

The production of energy goods is separated into fossil fuels, oil refining and gas manufacture and distribution, and electricity production. The production of fossil fuels (COL, GAS, CRU) combines sector-specific fossil-fuel resources with a Leontief (fixed-proportion) aggregate of intermediate inputs and a composite of primary factors and energy, described by a Cobb-Douglas function of energy inputs, capital, and labor. Oil refining (OIL) and gas manufacture and distribution (GDT) are described similarly to the production of other goods, but with a first-level Cobb-Douglas nest combining the associated fossil-fuel inputs (crude oil for oil refining; and coal, crude oil, and natural gas for gas manufacture and distribution) with material inputs and the capital-labor-energy (KLE) nest. Electricity production is described by a Leontief nest which combines, in fixed proportions, several generation technologies, including nuclear, hydro, and wind power, as well as conventional power generation based on fossil fuels. Non-fossil-fuel generation is described by a CES nest combining specific resources and a capital-labor aggregate.

All industries are characterized by constant returns to scale and are traded in perfectly competitive markets. Capital mobility is represented in each sector by following a putty-clay approach in which a fraction of previously installed capital becomes non-malleable in each sector. The rest of the capital remains mobile and can be shifted to other sectors in response to price changes. The modeling of international trade follows Armington's (1969) approach of differentiating goods by country of origin. Thus, goods within a sector and region are represented as a CES aggregate of domestic goods and imported ones with associated transport services. Goods produced within China are assumed to be closer substitutes than goods from international sources to replicate a border effect.

Final consumption in each region is determined by a representative agent who maximizes consumptions subject to its budget constraint. Consumption is represented as a CES aggregate of non-energy goods and energy inputs and the budget constraint is determined by factor and tax incomes with fixed investment and public expenditure.

3.2. Database and aggregation

The model is calibrated to a comprehensive energy-economic data set which includes a consistent representation of energy markets in physical units, as well as detailed accounts of regional production and bilateral trade for the year 2007. The dataset is global, but includes regional detail for China's provinces. The global data comes from the database version 8 of the Global Trade Analysis Project (GTAP). The GTAP 8 data set provides consistent global accounts of production, consumption and bilateral trade as well as consistent accounts of physical energy flows, energy prices and emissions in the year 2007, and identifies 129 countries and regions and 57 commodities (Narayanan et al., 2012). Since in this study, we are primarily interested in the economic and distributional effects among Chinese provinces, we aggregate the international data into three international regions (USA, Europe, and the rest of the world) to capture the international market impacts of distributional changes within China. With respect to commodities, we include six energy sectors and 10 non-energy composites.[10]

[10] The energy goods include coal (COL), crude oil (CRU), refined-oil products (OIL), natural gas (GAS), gas manufacture and distribution (GDT), and electricity (ELE); the non-energy sectors include agriculture (AGR), minerals mining (OMN), light industries (LID), energy-intensive industries (EID), transport equipment (TME), other manufacturing industries (OID), water (WTR), trade (TRD), transport (TRP), other service industry (OTH).

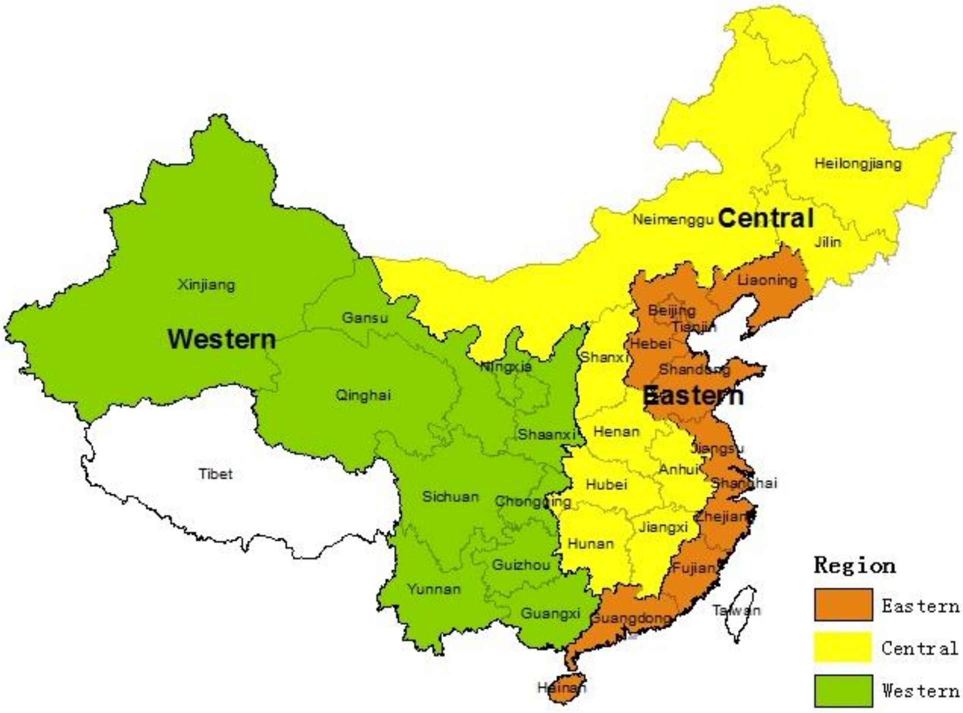

Figure 2. Overview of Chinese provinces included in the analysis.[11]

The data for China is based on China's national input-output table and the full set of China's provincial input-output tables published in 2007 (National Information Center of China, 2011). The provincial input-output data for China specifies benchmark economic accounts for 30 provinces in China (Tibet is not included due to a lack of data and the small scale of its economic activities). Energy use and emissions data is based on the 2007 China Energy Statistical Yearbook (National Statistics Bureau of China, 2008). Zhang et al. (2012) describe in detail the method used for balancing the Chinese data set and combining it with the international one. Elasticities of substitution are adopted from the GTAP 8 database, as well as from the MIT Emissions Prediction and Policy Analysis model (Paltsev et al., 2005), in particular for the price elasticities of supply of nuclear, hydro, and wind. Table A1 in the appendix provides an overview of the elasticities used in this study.

Figure 2 shows the provinces included in the analysis. We explicitly simulate the policy scenarios' effects for all 30 Chinese provinces for which data is available. To ease the presentation of results, we group those provinces according to the three economic zones defined in China's 7th FYP (State Council of China, 1986; Feng et al., 2012), i.e., into eastern, central, and western ones. The eastern provinces are the economically most developed regions with high levels of industrialization and rapid growth in international trade. Based on the Chinese database, Table 1 indicates that the eastern provinces' total GDP

[11] The eastern provinces include Beijing (BEJ), Fujian (FUJ), Guandong (GUD), Hainan (HAI), Hebei (HEB), Jiangsu (JSU), Liaoning (LIA), Shandong (SHD), Shanghai (SHH), Tianjin (TAJ), and Zhejiang (ZHJ); the central provinces include Anhui (ANH), Heilongjiang (HLJ), Henan (HEN), Hunan (HUN), Hubei (HUB), Jiangxi (JXI), Jilin (JIL), Neimenggu (NMG), and Shanxi (SHX); the western provinces include Chongqing (CHQ), Gansu (GAN), Guangxi (GXI), Guizhou (GZH), Ningxia (NXA), Qinghai (QIH), Shannxi (SHA), Sichuan (SIC), Xinjiang (XIN), and Yunnan (YUN).

is more than double that of the central provinces and more than four times that of western provinces. They are also the greatest emitters of CO_2 in China. However, due to their economic development they have the lowest emissions intensity. The central provinces have well-established infrastructures and abundant natural resources, such as coal, oil, and metal ores. They are relatively less developed compared to the eastern provinces, although provinces, such as Inner Mongolia (Neimenggu) are industrializing rapidly. The central provinces' total emissions are more than 30% lower than those of the eastern provinces, but their emissions intensity is 65% higher (Table 1). The western provinces are the least developed ones, but provinces such as Xinjiang have abundant oil and natural-gas reserves. The western provinces' total emissions are more than 50% lower than those in the eastern provinces, but their emissions intensity is almost double (Table 2).

Table 1. Regional emissions, GDP, and emissions intensities.

	Emissions ($MTCO_2$)	GDP (billion Yuan)	EI ($MtCO_2$/billion Yuan)
Eastern	2501	17130	0.15
Central	1704	7089	0.24
Western	1162	4074	0.29
China	5368	28295	0.19

4. Model scenarios

This study considers four model scenarios to compare and contrast the economic and distributional effects of implementing consumption-based emissions-intensity targets, either as individual targets for Chinese provinces, or as baseline allocation for a national emissions-trading system in China. The scenarios considered differ with respect to their method of allocating the emissions-intensity targets and baseline allowances. The production-based (**PAP**) scenario follows a territorial and production-based accounting principle and allocates the same percentage emissions-intensity target to each province; the politics-based (**POL**) scenario follows the political decision-making process and adopts the emissions-intensity allocation that was politically negotiated for the 12th FYP; the consumption-based (**CAP**) scenario follows a consumption-based accounting principle and adjusts emissions-intensity targets for interregional emissions transfers; lastly, the shared-responsibility (**SHR**) scenario takes a median approach in which emissions responsibilities and intensity targets are equally divided between the production-based principle and the consumption-based one.

For obtaining the interregional emissions transfers we apply a recursive diagonalization algorithm as described in Böhringer et al. (2011) and outlined in Appendix 2. Each scenario targets an emissions-intensity reduction of 17.4% nationally, which is in line with the target adopted by the Chinese government in its 12th FYP.[12] Figure 3 provides an overview of China's interregional emissions transfers as calculated in this study. On net, the eastern provinces import about 350 $MtCO_2$ of embodied emissions, i.e., 14% of their territorial emissions. Sixty percent of those emissions (212 $MtCO_2$) are embodied in imports from the central provinces and 40% (136 $MtCO_2$) in imports from the western provinces. The percentage emissions transfers for individual regions can be much larger than the average. For example, the eastern provinces of Zhejiang, Hainan, and Beijing each import embodied emissions which amount to more than 70% of their territorial emissions. On the other hand, the central province of Inner Mongolia (Neimenggu) and the western province of Guizhou each export embodied emissions which amount to more than 40% of their territorial emissions.

Adjusting the regional emissions-intensity targets on a consumption basis leads to a greater reduction burden for the eastern provinces and less burden for the central and western provinces. Table 2 (top panel) lists the trade-adjusted emissions-intensity reduction targets which were obtained by applying the methodology outlined in Section 2, in particular Eqs. (7), (13), and (15). The reduction burden for the eastern provinces in the consumption-based (CAP) scenario increases by 10.4 percentage points (60%) compared to the production-based (PAP) scenario with homogenous reduction targets. At the same time, the reduction burden for the central and western provinces is reduced by 10 and 8 percentage points (55% and 49%) respectively. In comparison, the politics-based (POL) scenario is associated with a much milder redistribution of reduction burden. In that scenario, the eastern provinces' reduction targets are increased by a mere 1.2 percentage points (7%) compared to the PAP scenario, while the central and western provinces' reduction targets are decreased by 0.6 and 1.7 percentage points (4% and 10%) respectively. Lastly, the shared-responsibility (SHR) scenario yields emission-intensity reduction targets that are given by the average between the production-based and the consumption-based targets. Thus, the eastern provinces' reduction burden increases by 5 percentage points (30%) compared to the production-based scenario, while the burden of the central and western provinces decreases by 5 and 4 percentage points (27% and 24%) respectively.

[12] Although we adopt the emissions-intensity target of the 12th FYP, we do not aim to simulate its future economic impacts. Instead our objective is to gain insights into the relative economic and distributional impacts of different approaches for allocating emissions-intensity targets. To better isolate the effects relevant for this analysis, we use a static (instead of a dynamic) CGE framework based on data representing economic conditions for the year 2007.

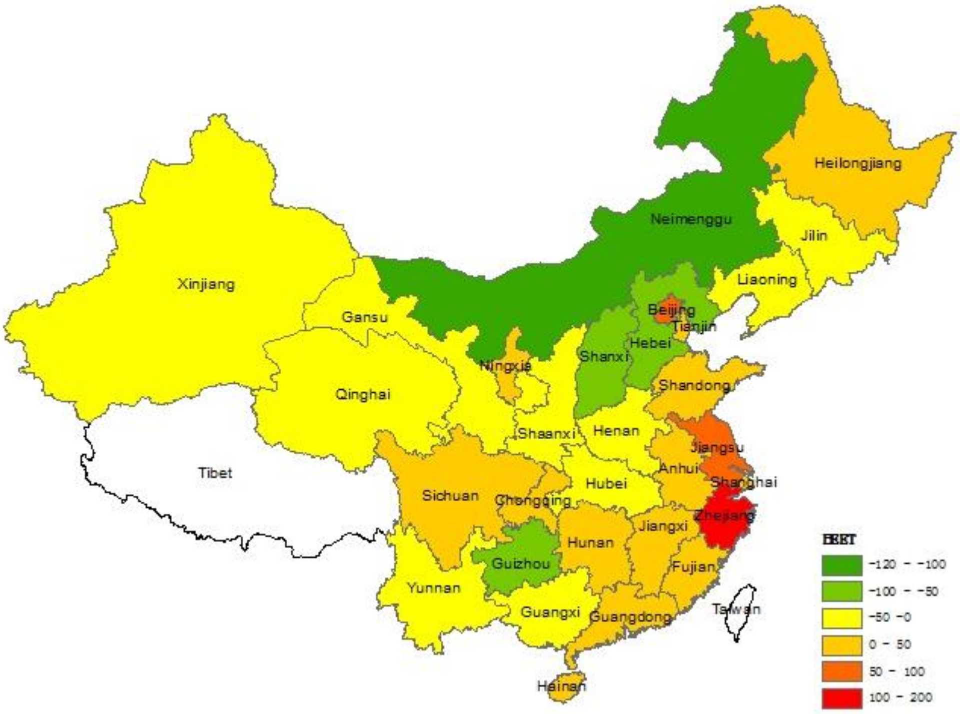

Figure 3. Emissions transfers between China's provinces. Positive numbers indicate a greater share of emissions embodied in imports than those embodied in exports (see Eq. 4).

Paralleling emissions transfers, the trade-adjusted emissions-intensity targets show a larger spread than the averages suggest. Especially the heavily importing eastern provinces of Zhejiang, Hainan, and Beijing are burdened greatly when following a consumption-based approach for target allocation. Their targets for emissions-intensity reductions increase from 17.4% to over 85%. On the other hand, the reduction targets for several emissions-exporting central and western provinces, such as Inner Mongolia and Shanxi (central), and Gansu, Guizhou, Qinghai, and Yunnan (western) become zero in the consumption-based approach.[13]

We have chosen to report the model scenarios' impacts in terms of regional aggregates (eastern, central, and western provinces) to align the analysis with those perceived regional and political boundaries, and for ease of presentation. However, Figure 3 indicates that those regional boundaries do not map exactly to net emissions-exporting and emissions-importing provinces. Among the net emissions-importing provinces are nine eastern provinces, four central, and three western ones; among the net emissions-exporting provinces are seven western provinces, five central, and two eastern ones. The heterogeneous composition of those two groups decreases the maximum and minimum values in the regional aggregates

[13] The emissions-intensity reduction targets of those provinces would actually become negative, i.e., allow for increases in emissions intensity. However, because we want to preserve incentives for not increasing emissions intensities on the provincial level, we constrain the maximum alleviation for emissions exporting provinces to be the homogenous reduction target of the production-based approach, i.e., 17.4%. The provinces that would exceed this alleviation are allocated their baseline emissions intensities, i.e., a zero percent reduction target.

used for reporting, which should be kept in mind when interpreting the results. The maximum and minimum economic impacts are mentioned in the results section wherever feasible to underline this distinction and the appendix provides a detailed overview of the economic impacts for each province.

Table 2. Regional emissions-intensity reduction targets (denoted by _r) and ETS baseline allocations (denoted by _n).

EI targets (%)	pap_r	pol_r	cap_r	shr_r
Eastern	17.4	18.6	27.8	22.6
Central	17.4	16.8	7.9	12.6
Western	17.4	15.7	9.0	13.2
all	17.4	17.4	17.4	17.4
ETS allowances ($MtCO_2$)	pap_n	pol_n	cap_n	shr_n
Eastern	2066	2037	1805	1936
Central	1408	1419	1569	1489
Western	960	980	1058	1009
all	4434	4435	4432	4434

The large spread of reduction targets on the provincial level can lead to great economic inefficiencies, considering that marginal abatement costs are especially high in many emissions importing eastern provinces which would need to shoulder a much greater reduction burden under the consumption-based approach for provincial target allocation. As a second application in this study, we therefore apply the consumption-based approach to allocate baseline emissions under a national emissions-trading system.[14] Instead of provincial emissions-intensity target, we prescribe a national emissions-intensity target of 17.4% and distribute baseline emissions allowances according to the absolute emissions targets that correspond to the percentage reduction targets discussed above. The absolute emissions allowances have been calculated based on the methodology outlined in Section 2, in particular by multiplying Eqs. (6), (12), and (14) by regional GDP. The absolute emissions allowances are listed in the lower panel of Table 2. On an absolute emissions basis, the baseline allocation of absolute emissions targets is equivalent to the distribution of emissions-intensity targets discussed above.

5. Results

This section analyzes the economic and distributional impacts of adopting a consumption-based approach to allocate a national 17% emissions-intensity reduction target among Chinese provinces. While this target has the same value as the one adopted in China's 12th FYP, our objective is not to simulate the future impacts of China's 12th FYP, but to illustrate the effects of different emissions-intensity target allocations. For that purpose, we use the static CGE model of Chinese economy outlined in Section 3. We model two applications of

[14] In the static general-equilibrium framework adopted in this study, an emissions-trading system based on absolute emissions is equivalent to one based on emissions-intensities (Ellerman and Sue Wing, 2003).

the consumption-based approach as described in Section 4. First, we analyze the effects of implementing regionally differentiated consumption-based emissions-intensity targets. Second, we use the consumption-based target-setting methodology developed in Section 2 to allocate baseline emissions under a national emissions-trading system.

5.1. Effects of trade-adjusting provincial emissions-intensity targets

Implementing consumption-based and regionally differentiated emissions-intensity targets in China can be expected to lead to significant differences in economic and distributional impacts between China's provinces, especially when considering the large spread of reduction targets listed in Table 3. To capture those impacts sufficiently, we divide the analysis into three levels of increasing macroeconomic detail which consider the regional, provincial, and sectoral impacts.

5.1.1. Impacts on the regional level

This study assesses macroeconomic welfare effects in terms of Hicksian equivalent variation of income. The scenarios' effects on regional welfare are listed in Table 3 (top panel). The production-based scenario which implements homogenous emissions-intensity reductions of 17.4% for each province leads to the greatest welfare losses in the central provinces (-2.26%) relative to the no-policy case. The decreases in welfare are about a third less in the central provinces (-1.5%) and another third less in the eastern provinces (-0.87%) who are the least burdened. The politics-based scenario changes those trends only marginally. The eastern provinces' welfare decreases by 0.1 percentage points more than in the production-based scenario, with little alleviation of negative welfare impacts for the central and western provinces.

The consumption-based scenario increases the reduction burden for the eastern provinces by 60% and decreases the burden for central and western provinces by about 50% each when compared to the production-based scenario. As a result, the eastern provinces become the highest burdened ones among China's regions, experiencing a more than four times larger negative welfare impact than in the production-based scenario. Their decreases in welfare are about two times larger than those of the central and eastern provinces. While the central provinces experience a 16% lower decrease in welfare than in the production-based scenario, the welfare loss in the western provinces is 20% larger than in the production-based scenario despite the substantial alleviation of reduction burden for those provinces in the consumption-based scenario. The national welfare loss more than doubles in the consumption-based scenario compared to the production-based and politics-based scenarios.

Table 3. Regional changes in welfare as measured by equivalent variation of income (top) and regional changes in GDP (bottom).

EV (%)	pap_r	pol_r	cap_r	shr_r
Eastern	-0.87	-0.96	-3.64	-1.20
Central	-2.26	-2.23	-1.90	-2.00
Western	-1.50	-1.44	-1.79	-1.43
CHN	-1.36	-1.39	-2.84	-1.46
GDP (%)				
Eastern	-0.32	-0.35	-1.27	-0.43
Central	-1.05	-1.04	-0.92	-0.94
Western	-0.69	-0.69	-0.85	-0.67
CHN	-0.56	-0.57	-1.12	-0.59

The shared-responsibility scenario largely remedies the negative effects that the consumption-based scenario has on national welfare. The national welfare loss in the shared-responsibility scenario is about 7% and 4% larger than in the production-based scenario and the politics-based scenario respectively (compared to 109% in the consumption-based scenario). Although the eastern provinces are again the least burdened in the shared-responsibility scenario, the welfare losses for the central and western provinces are both reduced compared to the production-based and politics-based scenarios, by 12% and 4% respectively.

Changes in GDP follow the same directional trends as the changes in equivalent variation.
Table 3 (lower panel) lists the changes in GDP for the policy scenarios considered. In principle, changes in GDP can differ from changes in equivalent variation as GDP focuses solely on the production side of the economy. Although the changes in GDP are less accentuated than the changes in EV, they follow the same direction in similar proportions. A full list of GDP effects is provided in Table A3 in the appendix.

5.1.2. Impacts on the provincial level

Individual provinces can bear much greater welfare impacts than the impacts for the aggregate regions suggest. Figure 4 highlights the five provinces which are burdened the most and the five which are burdened the least under the consumption-based scenario. A complete listing of welfare impacts is provided in Table A2 in the appendix. Three of the highest burdened provinces are in the east (Hainan, Zhejiang, Beijing), while one is in the center (Shanxi) and one in the west (Chongqing). With the exception of Shanxi, all of those provinces are net importers of embodied emissions and are therefore subjected to greater reduction targets in the consumption-based scenario. Shanxi is China's greatest coal producer, possessing about one third of China's coal reserves. It is therefore impacted significantly by all policies aimed at reducing China's emissions intensity. The welfare losses of the five highest burdened provinces cover a large range, spanning percentage welfare changes of -6 to -33% compared to the no-policy case. Those losses correspond to 2 to 22 times the magnitude of losses found in the production-based scenario.

Among the five least burdened provinces in the consumption-based scenario are two western (Gansu, Guizhou), two central (Hubei, Henan), and one eastern province (Hebei). All of those provinces are net exporters of embodied emissions and therefore are subjected to less stringent reduction targets in the consumption-based scenario. Three out of the five (Gansu, Guizhou, and Hebei) have a zero reduction target, i.e., they are allowed to keep their baseline emissions intensities due to their high exports of embodied emissions. The positive welfare effects in those provinces do not reach similar magnitudes as the negative ones. The welfare gains range from 1% to 2% compared to the no-policy case, which corresponds to factor increases of 0.5 to 5 compared to the production-based scenario's welfare levels. Hubei and Guizhou are important energy producers, in particular for electricity generation. Those provinces experience welfare gains in all policy scenarios as the price for electricity increases following the mandated reductions in emissions intensity.

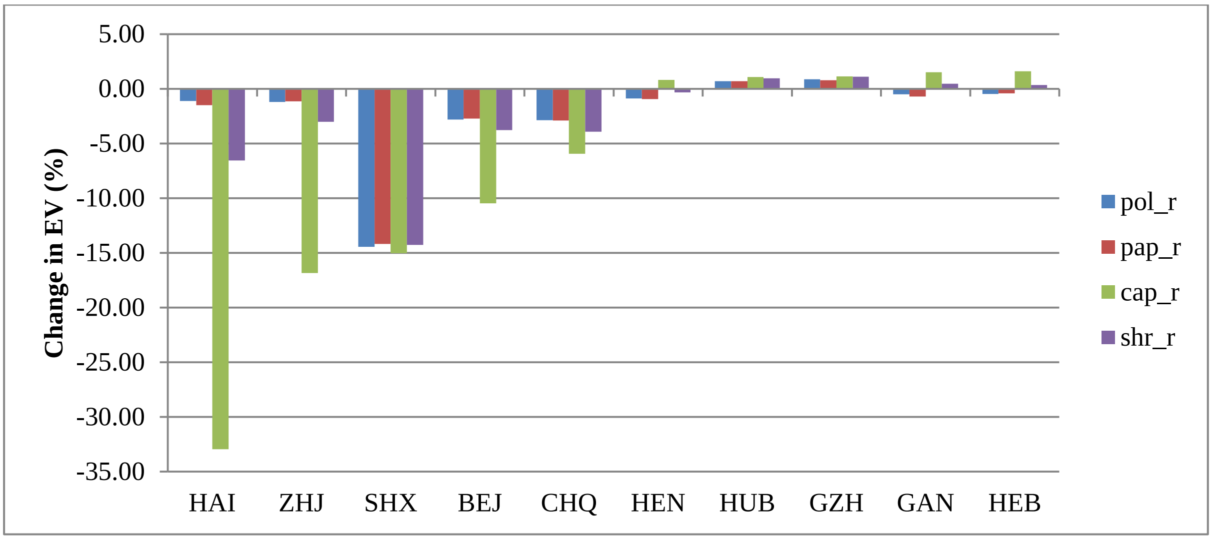

Figure 4. Changes in equivalent variation of income (EV) for the five provinces burdened most and those burdened least under a consumption-based adjustment of emissions-intensity targets. Regional abbreviations are listed in the footnote to Figure 1.

5.1.3. Impacts on the sectoral level

The analysis on the provincial level shows that adjusting emissions-intensity targets for emissions transfers has a highly differentiated impact on China's provinces. The gains and losses of such adjustment can cover one order of magnitude compared to a homogenous distribution of targets or the politically negotiated ones. A sectoral analysis can provide further insights into the underlying causes of those impacts. Of specific interest for analyzing the sectoral impacts of policies targeting reductions in emissions intensity are the fossil-fuel sectors which produce emissions, and the sectors which are direct substitutes or have high emissions inputs, such as the electricity and energy-intensive sectors. Table 4 lists the output and price changes in those sectors for the model scenarios considered.

Table 4. Regional changes in output and prices for the coal (COL), electricity (ELE), and energy-intensive (EID) sectors.

		Output changes (%)				Price changes (%)			
Sector	Region	pap_r	pol_r	cap_r	shr_r	pap_r	pol_r	cap_r	shr_r
COL	Eastern	-24.5	-25.2	-28.4	-26.5	-8.2	-8.2	-7.8	-8.2
	Central	-12.0	-12.1	-11.4	-12.2	-11.4	-11.4	-11.1	-11.4
	Western	-20.1	-19.4	-16.9	-18.7	-8.8	-8.7	-8.0	-8.5
	China	-16.8	-16.8	-16.5	-17.0	-10.1	-10.1	-9.7	-10.1
ELE	Eastern	-14.9	-16.4	-29.4	-23.7	17.2	18.4	19.8	18.7
	Central	-16.2	-15.3	-2.2	-9.2	15.9	15.6	12.2	13.1
	Western	-13.1	-11.2	-3.9	-8.4	10.2	9.6	7.8	8.6
	China	-14.9	-15.1	-16.9	-16.7	15.5	15.9	14.6	14.9
EID	Eastern	-3.8	-4.5	-10.3	-5.5	2.4	2.5	3.0	2.6
	Central	-3.8	-3.3	4.1	-1.5	3.0	3.0	2.3	2.5
	Western	-7.7	-6.6	0.4	-4.9	3.7	3.6	3.0	3.2
	China	-4.3	-4.5	-5.2	-4.4	2.7	2.8	2.8	2.7

The Chinese primary energy mix is dominated to about 70% by coal resources (NBS China, 2008). Emission-intensity targets induce a substitution away from energy-intensive coal to less energy-intensive energy carriers, such as natural gas and renewable resources. Table 4 indicates that coal production is reduced by about 17% in each policy scenario. The price for coal reduces due to the decreasing demand by about 10% on aggregate. In accordance to the distribution of emissions-intensity targets, the reductions in coal production are higher in the eastern provinces (24-28%) than in the central and western ones (11-12% and 17-20% respectively). This trend is most accentuated in the consumption-based scenario. The western provinces increase their coal production by 3 percentage points (15%) in the consumption-based scenario relative to the production-based one, while the eastern provinces decrease their production by 4 percentage points (17%).

The implementation of regional targets for reducing emissions intensity creates an implicit price for emissions inputs. This increases the prices for affected commodities, such as electricity and energy-intensive goods, which reduces output. Table 4 indicates that the price for electricity increases by 15-16% in each policy scenario on aggregate, inducing output reduction of similar percentages (15-17%). There are big differences across the scenarios on the provincial level. While the percentage output reductions in electricity are relatively evenly distributed in the production-based scenario (13-16%), the range widens in the other policy scenarios, in particular in the consumption-based one (2-29%). In the latter the eastern provinces are allocated more stringent emissions-intensity reduction targets. As a result, those provinces seek to substitute domestic electricity generation which would increase their emissions intensity with electricity imports from other provinces. This decreases electricity generation in the eastern provinces (by 15 percentage points compared to the production-based scenario), but increases generation in the central and western provinces (by 14 and 9 percentage points, respectively, compared to the production-based scenario). Similar trends can be observed for energy-intensive goods. Prices increase by about 3 percentage points in each scenario on aggregate and output decreases by 4-5 percentage points. Again, the eastern provinces exhibit a decrease of energy-intensive production, while the central and western provinces exhibit an increase (of about 8 percentage points each).

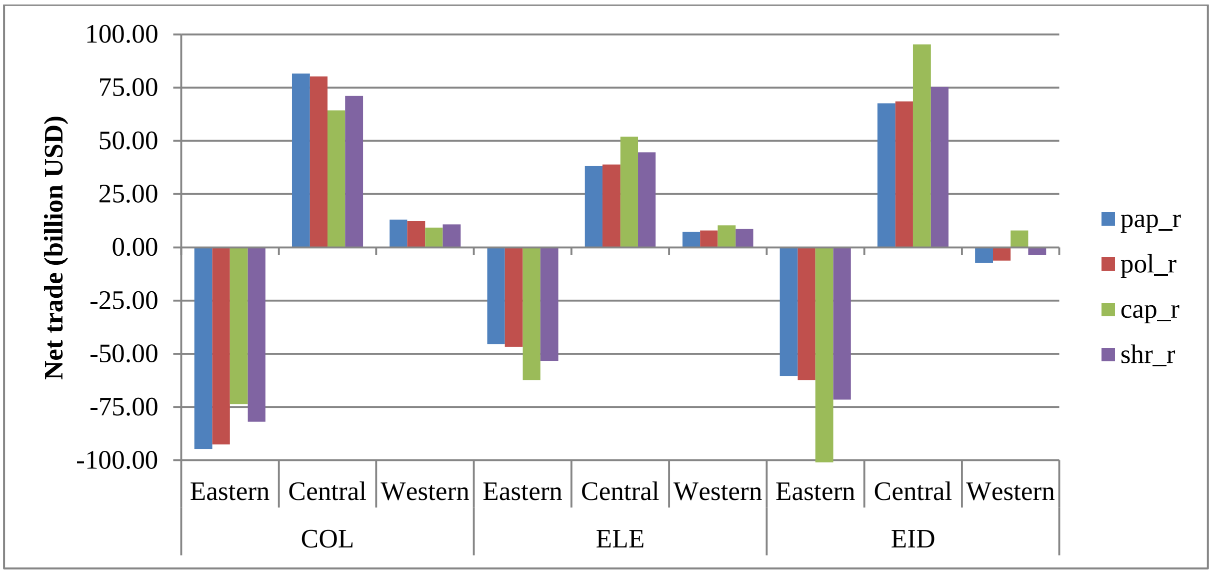

Figure 5. Regional net trade flows (exports minus imports) in billion USD for the coal (COL), electricity (ELE), and energy-intensive (EID) sectors.

Associated with changes in output and prices are changes in trade flows. Figure 5 displays China's interregional net trade flows (i.e., exports minus imports) in billion USD. In line with the output changes discussed above, coal imports by the eastern provinces decrease by 22% in the consumption-based scenario compared to the production-based one. At the same time, the eastern provinces' electricity and energy-intensive imports increase by 37% and 71% respectively. The corresponding exports of the central and western regions increase by 37% and 41% for electricity, and by 41% and 209% for energy-intensive goods. Thus, implementing the consumption-based emissions-intensity targets results in significant outsourcing of energy and energy-intensive production from the eastern provinces to the central and western ones.

5.1.4. Feedback on emissions transfers

The outsourcing effect has further repercussions on emissions embodied in trade and interprovincial emissions transfers. Figure 6 displays the interregional emissions transfers resulting from the policy scenarios considered. In the consumption-based scenario, the emissions transfers from the eastern provinces to others increase by about 12 $MtCO_2$ (4%) compared to the benchmark. The consumption-based approach to regional target allocation therefore creates incentives which perpetuate the imbalance of consumption-based emissions it seeks to address. As a consequence, the regional differences in reduction targets and the economic effects resulting from those, such as sectoral specialization and outsourcing, can be expected to increase with each iteration of target setting.

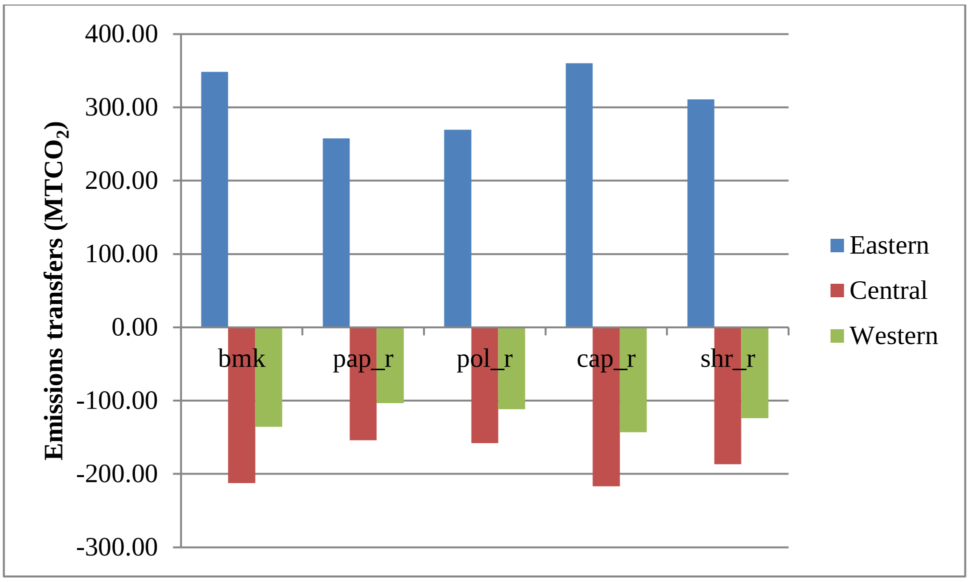

Figure 6. Emissions transfers (emissions embodied in imports minus emissions embodied in exports) in the benchmark and regional policy scenarios.

Figure 6 indicates that all other policy scenarios result in a decrease of emissions transfers from the eastern provinces to the central and western ones. The decreases amount to 26% and 23% in the production-based and politics-based scenarios respectively, and to 11% in the shared-responsibility scenario. The latter indicates that the economic and emissions unbalancing effects of the consumption-based approach can be remedied by weighing the consumption-based emissions responsibilities with other allocation metrics, such as the production-based responsibilities in the shared-responsibility scenario. Thus, the equity criterion of considering the responsibilities of consumers for the emissions generated in the production process of the goods demanded need not be abandoned completely.

5.2. Effects of trade-adjusting emissions allocation of a national ETS

This section analyzes whether the problems associated with the consumption-based allocation of regional emissions-intensity targets, such as the potential overburdening of emissions-exporting regions and the unbalancing effects on emissions transfer, can (in addition to weighing consumption-based responsibilities with other metrics) be remedied by allowing provinces to trade emissions permits with each other. In theory, an emissions-trading system (ETS) allows for emissions-intensity reduction to occur where they are cheapest. Economic efficiency will be reached irrespective of the baseline allocation of emissions allowances, so that efficiency and equity considerations can be addressed separately. We therefore consider the same scenarios as in the previous section (PAP, POL, CAP, SHR), with the difference that the associated methods for emissions accounting are used for distributing the provincial baseline emissions allowances instead of the provincial emissions-intensity targets. To completely define the ETS, a national emissions-intensity cap of 17.4% is implemented which corresponds to the reduction in emissions intensity reached in the regional scenarios. The distribution of emissions allowances across the model scenarios and regions is listed in Table 2.

The following sections analyze the allocative, welfare and sector-level impacts of the ETS scenarios and compare those to the impacts of the regional-target scenarios discussed above.

5.2.1. Comparison of emissions-intensity reductions and trade in emissions permits

In the regional-target scenarios, the reduction burden is shifted from the central and western provinces to the eastern ones when going from the production-based scenario to the consumption-based and shared-responsibility ones. In contrast, the distribution of emissions-intensity reductions is not regionally mandated in the ETS scenarios. Instead, provinces with high marginal abatement costs are allowed to purchase emissions permits from provinces with lower abatement costs. The trade in emissions permits results in the equalization of marginal abatement costs across provinces and in a cost-efficient distribution of emissions-intensity reductions.

The deviation from the cost-efficient distribution of emissions-intensity reductions in the ETS scenarios highlights the inefficiencies of allocating emissions-intensity reductions among provinces. Figure 7 indicates that the western and central provinces reduce their emissions intensities significantly more in the ETS scenarios, and the eastern provinces less, than in the regional target scenarios. Especially the distribution of emissions-intensity reduction in the regional consumption-based scenario contrasts sharply with that of the ETS scenarios. The greatest emissions-intensity reductions are undertaken by the eastern provinces in the former, but by the western provinces in the latter.

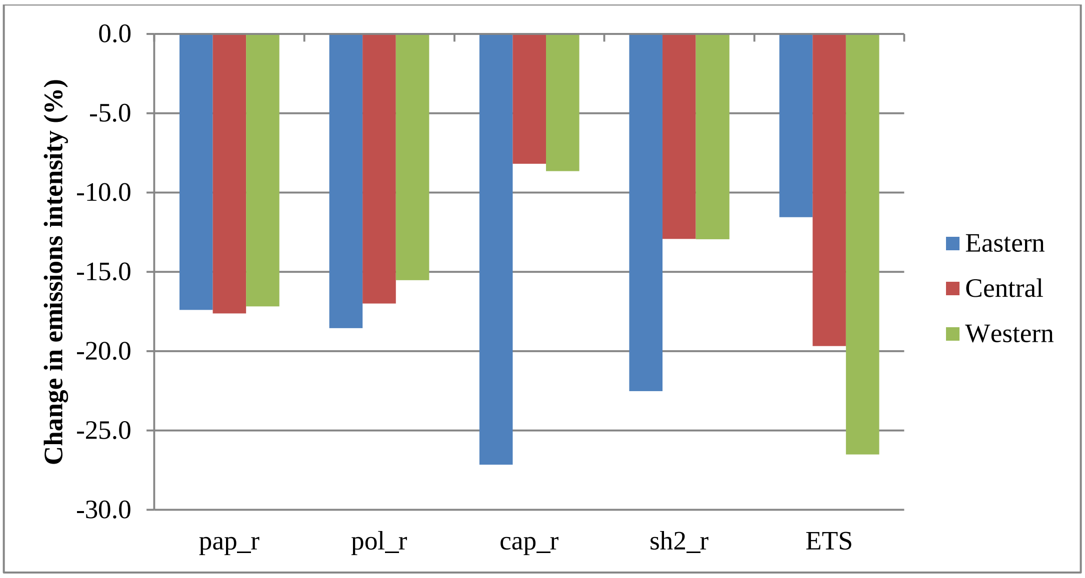

Figure 7. Regional changes in emissions intensity for the regional reduction scenarios and the ETS one(s). The change in emissions intensity obtained under an ETS is the same in all scenarios considered.

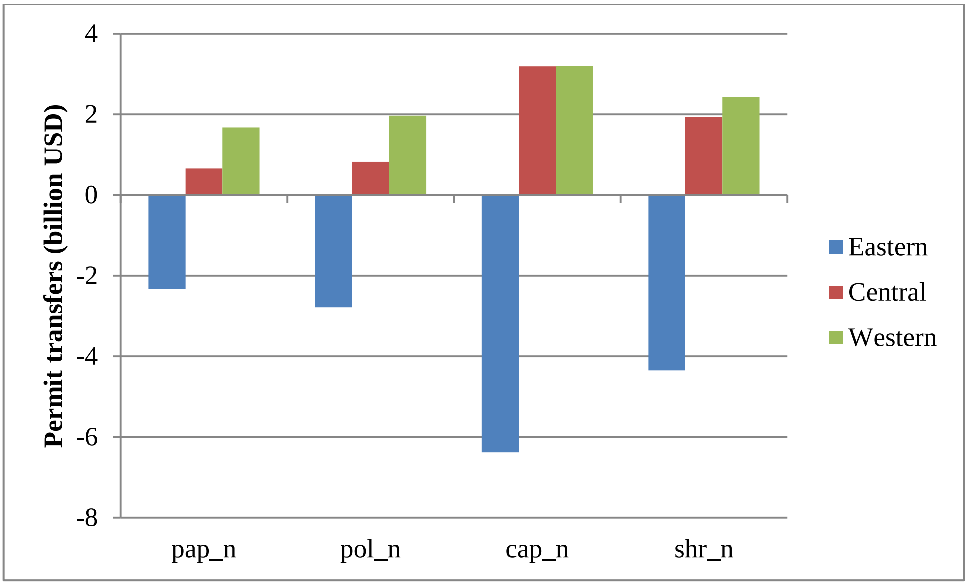

Figure 8. Regional trade in emissions permits in billion USD. Negative numbers indicate purchases of emissions permits, positive numbers indicate sales.

While the regional distribution of emissions and emissions-intensity reduction is identical in each ETS scenario, the trade in emissions permits differs depending on the initial allocation of allowances. Figure 8 analyzes the distributional implications of the trade in emissions permits. In all ETS scenarios, the eastern provinces are net buyers of emissions permits, while the central and western provinces are net sellers. The value of permit purchases increases from about USD 2.3 billion in the ETS scenario with a production-based allocation of initial allowances to about USD 6.4 billion in the ETS scenario with a consumption-based allocation of initial allowances. The provinces purchasing the most emissions permits in the consumption-based ETS scenario are Zhejiang (USD 2.8 billion), Jiangsu (USD 1.2 billion), and Beijing (USD 1.1 billion); the provinces selling the most permits in the consumption-based ETS scenario are Hubei (USD 1.3 billion), Yunnan (USD 1.2 billion), and Guizhou (USD 1 billion). Table A4 in the appendix provides a complete list of permit sales and purchases by province.

5.2.2. Comparison of welfare effects

Greater cost-efficiency of emissions-intensity reductions in an ETS leads to reductions in welfare losses. Table 5 lists the regional welfare impacts of the different ETS allocation methods associated with the model scenarios. Compared to the welfare impacts of the regional target allocation discussed above (see Table 3), the national welfare loss is reduced by 20% (0.3 percentage points) in the ETS scenarios. In line with the principle that economic efficiency is reached irrespective of the initial allocation of emissions permits (Coase, 1960), the national welfare effects are the same across all the policy scenarios considered. However, the distribution of regional impacts differs between the scenarios. The production-based ETS scenario and the politics-based one show proportionally similar distributions of welfare effects as the corresponding regional target scenarios. The eastern provinces are burdened the least, while the central ones are burdened the most.

Table 5. Percentage changes in equivalent variation of income in the ETS scenarios (_n) for China's regions and the provinces most burdened by the consumption-based regional scenario (cap_r).

EV (%)	pap_n	pol_n	cap_n	shr_n	cap_r
Eastern	-0.63	-0.69	-1.14	-0.89	-3.64
Central	-1.96	-1.92	-1.29	-1.63	-1.90
Western	-1.01	-0.89	-0.40	-0.70	-1.79
CHN	-1.06	-1.06	-1.05	-1.06	-2.84
HAI	-1.33	-1.05	-4.45	-2.89	-32.95
ZHJ	-1.00	-1.06	-4.04	-2.52	-16.84
SHX	-12.76	-12.71	-10.41	-11.59	-15.03
BEJ	-2.28	-2.30	-4.70	-3.49	-10.47
CHQ	-2.67	-2.65	-3.72	-3.19	-5.94

In contrast, the consumption-based ETS scenario exhibits qualitatively different welfare impacts than the consumption-based regional one. In the latter, only the central provinces gain relative to the regional production-based scenario. However, in the consumption-based ETS scenario, both the central and the western provinces experience gains in welfare compared to the production-based ETS scenario. Their welfare increases by 34% and 61%

respectively. In the consumption-based ETS scenario, the eastern provinces still experience a relative welfare loss compared to the production-based one, but the loss is reduced by a factor of three with respect to the consumption-based regional scenario (from 320% to 80% loss in percentage terms). The effects can be greater for individual provinces. Table 5 indicates that the welfare losses of the five highest burdened provinces are reduced by factors of two to seven in the consumption-based ETS scenario relative to the consumption-based regional one.

Again, the shared-responsibility scenario dampens the effect of the consumption-based scenario. In the ETS application, the eastern provinces' welfare decreases by 40%, while those of the central and western provinces increases by 17% and 30% respectively. Thus, the shared-responsibility ETS scenario halves the redistributional impacts of the consumption-based ETS scenario in percentage terms.

5.2.3. Comparison of impacts on the sectoral level

The outsource effect associated with increased emissions transfers which was found in the regional consumption-based scenario is remedied in the consumption-based ETS scenario. Figure 8 (left axis) compares the trade effects of the ETS and regional-target scenarios for the energy-intensive (EID) industries. Since the distribution of emissions-intensity reductions is the same in each ETS scenario, also the trade effects are equalized. In the ETS scenarios, EID imports by the eastern provinces are about halved compared to the consumption-based regional scenario, and of similar proportion as the production-based regional scenario. At the same time, EID exports of the central and western provinces are reduced by 30% and 231% compared to the consumption-based regional scenario, and reduced by 1% and 43% compared to the production-based regional scenario. Thus, the outsourcing of emissions-intensive production from the eastern provinces to the central and western ones is significantly reduced in the ETS scenarios and even lower than in the regional production-based scenario.

Figure 8 shows that changes in energy-intensive output is more aligned with emissions intensities and therefore also with marginal-abatement costs and the potential for emissions reductions. In the ETS scenarios, EID output in the western provinces decreases by 13% compared to the no-policy case, which is 8 and 12 percentage points more than in the central and eastern provinces. Compared to the regional scenarios, those output reductions are greater for the western and central provinces, but smaller for the eastern provinces. Nationally, the EID output losses in the ETS scenarios are 20% and 33% lower than those in the regional production-based and consumption-based scenarios. The relative impacts on the electricity and coal sectors in the ETS scenarios follow similar qualitative trends.

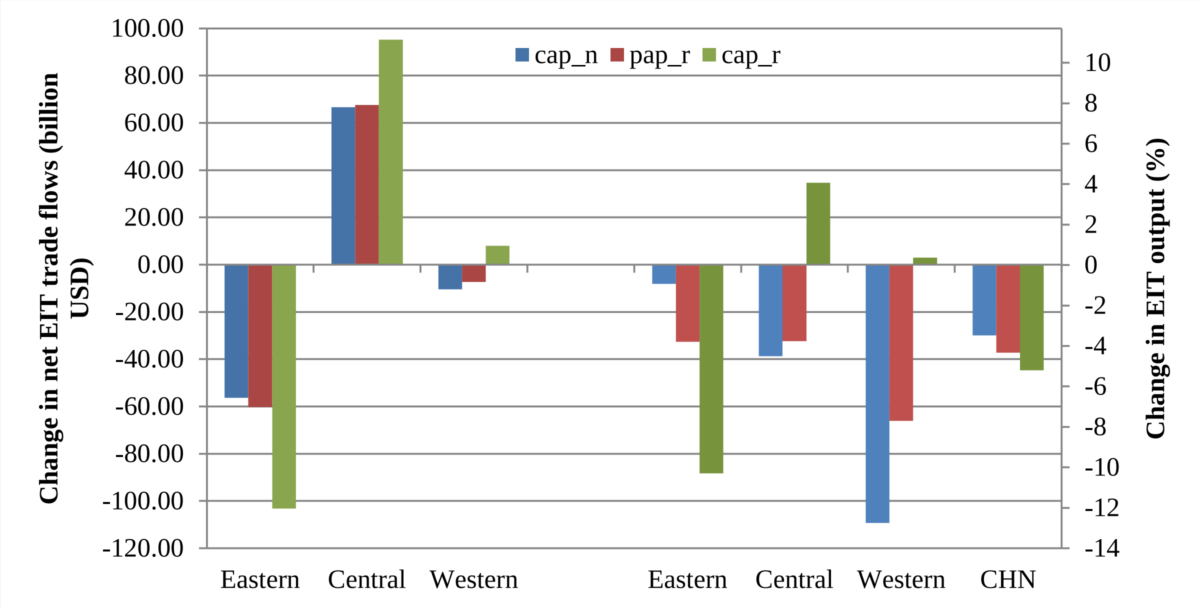

Figure 8. Absolute changes in net trade in energy-intensive goods (left axis) and percentage changes in output of energy-intensive goods (right axis).

6. Discussion and conclusion

Estimates of emissions embodied in trade and analyses of the distributional and political implications of consumption-based approaches to emissions accounting have been of great interest in the last years. While consumption-based emissions inventories are now regularly constructed for various countries and regions in the world, little attention has been devoted to the possible methods and potential economic effects of implementing consumption-based emissions responsibilities into actual policy making. This study addresses those two points by developing a consistent methodology for adjusting regional emissions-reduction targets for trade-induced emissions transfers and by simulating the economic effects following from their implementation for the context of China's 12th FYP and its allocation of emissions-intensity reduction targets among its provinces.

This study finds that in 2007 China's eastern provinces are net importers of emissions embodied in interregional trade, while the central and western provinces are net exporters. The magnitude of interregional emissions transfers from the eastern provinces to the central and western ones amounts to 14% of the eastern provinces' territorial emissions. Adjusting the regional emissions-intensity reduction targets for those emissions transfers increases the reduction burden for the eastern provinces by about 60% on aggregate, while alleviating the burden for the central and western provinces by 55% and 49%, respectively.

Our CGE analysis indicates that this redistribution of reduction burden could double China's national welfare loss compared both to a homogenous allocation of reduction burden under a production-based approach and to the politically adopted allocation of the 12th FYP. The results show that the welfare losses for the eastern provinces increase by a factor of four on aggregate and up to a factor of 22 for individual provinces. The central provinces' welfare losses are only slightly lowered when adopting consumption-based reduction targets, while those of the western provinces increase despite their lowered reduction burden.

The sectoral analysis indicates that the consumption-based allocation of reduction targets results in significant outsourcing of energy and energy-intensive production from the eastern provinces to the central and western ones. This is found to increase the interregional emissions transfers between those regions above benchmark levels. The consumption-based approach to regional target allocation as implemented in this study therefore creates incentives which perpetuate the imbalance of consumption-based emissions it seeks to address. As a consequence, the regional differences in reduction targets and the economic effects resulting from those, such as sectoral specialization and outsourcing, can be expected to increase with each iteration of consumption-based target setting. While those results hold strictly only for this study's model setup, they lend caution to an approach for allocating emissions-reduction burden based solely on consumption-based emissions responsibilities.

Another caveat of allocating emissions-intensity targets solely by a regional consumption-based approach is the potential interaction with those emissions that are embodied in international (instead of interregional) trade. In 2004, 22.5% of the emissions produced in China were embodied in good that were exported (Davis and Caldeira, 2010). Those export goods, in particular labor-intensive textile goods and wearing apparel are primarily produced in the eastern provinces, while a smaller portion of energy-intensive exports is produced in the central and western provinces (Guo et al., 2012). A comprehensive consumption-based adjustment of emissions-intensity targets would need to take into account those international emissions transfers, which however may raise conflicts with issues of national sovereignty.

This study has analyzed two potential remedies for the unbalancing effects of a consumption-based approach to target allocation, a shared-responsibility approach and emissions trading. The shared-responsibility approach divides emissions responsibilities between the consumer and the producer. It was found that allocating regional reduction targets by following this approach largely remedies the negative effects that an allocation that is solely based on the consumption-based approach has on national welfare. In particular, the national welfare loss is reduced to levels comparable with those under a production-based allocation. Welfare losses for the central and western provinces are slightly reduced compared to those of the production-based approach and the high welfare losses that the eastern provinces experience in the consumption-based approach decrease markedly. The outsourcing effects are also alleviated, so that emissions transfers from the eastern provinces to the central and western ones decrease below benchmark levels. The shared-responsibility approach thus demonstrates that integrating consumption-based emissions responsibilities with other allocation metrics, such as producer responsibilities, can constitute a potential option for future emissions-reduction allocations. The analytical part of this study provides the general methodology necessary for deriving a combined index for target allocation.

An emissions trading system that uses the various approaches to allocate allowances leads to improved welfare outcomes. In an ETS, economic efficiency will be reached irrespective of the initial allocation of emissions allowances. Thus, efficiency and equity considerations can be addressed separately. Allocating baseline emissions allowances by a consumption-based approach decreases the welfare losses of the central and western provinces by 31% and 69% more than the regional shared-responsibility approach, while increasing the welfare losses of the eastern provinces by 6% less (which correspond to a more than three-fold decrease in welfare losses compared to the regional consumption-based scenario). The regional distribution of emissions-intensity reductions is the same across all ETS scenarios due to the equalization of marginal abatement costs in an ETS. As a result, the western provinces which have relatively high emissions intensities decrease those the most, while the eastern provinces which have the lowest emissions intensities decrease them the least. The ETS approach therefore eliminates the incentive for outsourcing energy-intensive production as found in the regional consumption-based scenario, and instead leads to a regional convergence of emissions intensities, which may have further beneficial impacts on easing regional economic and developmental disparities.

The Chinese government has suggested that it may establish a national carbon trading system by 2015. Focusing on addressing economic concerns with an ETS and distributional ones with differing baseline allocations for the ETS may therefore be seen as more forward looking than devising different regional allocation mechanisms. This study has shown that the ETS allocation methods are analytically equivalent to methods for regional target allocation, so that results and allocation methods can be applied to an ETS without much modification. It has been noted that specific allocation methods, such as the consumption-based approach analyzed in this study, may necessitate improvements in emissions accounting to routinely estimate interregional emissions transfers (Peters, 2008). However, general improvements in that direction are underway (Wiedmann et al., 2011). For the Chinese context Han et al. (2011) stress the need for China to measure emissions more accurately and to establish the infrastructure necessary for implementing a Chinese ETS by 2015. Those efforts, while aimed at establishing an ETS in general, will be similarly beneficial for enabling different allocation methods, such as a consumption-based one, to be implemented.

Clearly the numerical results obtained in this study hold strictly only for the specific parameter values and assumptions adopted in our model framework. Importantly, our CGE analysis assumes that China's economy is characterized by perfectly competitive markets, something which is easily contestable. Zhang et al. (2012) test the effects of market distortions and parameter assumptions on the results obtained with their regional CGE model for China. They find that subsidized end-use prices for electricity increase regional welfare losses as costs are not passed through. Constraints on capital mobility have been found to lead to effects in the same direction, albeit without changing the direction of relative impacts between a regional target scenario and a national one with trading. Similar results can be expected to hold for this multi-scenario comparison. Nonetheless, additional modeling studies and parameter analyses for the Chinese context, in particular of the elasticities of substitution which can have significant effects on the supply and demand responses (Sue Wing, 2004;

Jacoby et al., 2006) are highly encouraged.

Acknowledgments

The authors gratefully acknowledge the financial support for this work provided by the MIT Joint Program on the Science and Policy of Global Change through a consortium of industrial sponsors and Federal grants, and by the AXA Research Fund which is supporting Marco Springmann's doctoral research. We further thank Eni S.p.A., ICF International, Shell International Limited, and the French Development Agency (AFD), founding sponsors of the China Energy and Climate Project. We also grateful for support provided by the Social Science Key Research Program from National Social Science Foundation, China of Grant No. 09&ZD029 and by Rio Tinto China. We would further like to thank John Reilly, Sergey Paltsev, Henry Jacoby and Audrey Resutek for helpful comments, discussion and edits.

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Appendix 1: Elasticities of substitution

Table A1. Reference values of elasticities of substitution in production and consumption

Parameter	*Substitution margin*	*Value*
σ_{en}	Energy (excluding electricity)	1.0
σ_{enoe}	Energy—electricity	0.5
σ_{eva}	Energy/electricity--value-added	0.5
σ_{va}	Capital—labor	1.0
σ_{klem}	Capital/labor/energy—materials	0
σ_{cog}	Coal/oil—natural gas/fuel gas in ELE	1.0
σ_{co}	Coal—oil in ELE	0.3
σ_{gf}	Gas—fuel gas in ELE	10
σ_{hr}	Resource—Capital/labor/energy/materials in hydro ELE	1.0*
σ_{nr}	Resource—Capital/labor/energy/materials in nuclear ELE	1.0*
σ_{wr}	Resource—Capital/labor/energy/materials in wind ELE	1.0*
σ_{var}	Resource—Capital—Labor in AGR and OMN	1.0
σ_{rklm}	Capital/labor/materials—resource in primary energy	0
σ_{ct}	Transportation—Non-transport in private consumption	1.0
σ_{ec}	Energy—Non-energy in private consumption	0.25
σ_{c}	Non-energy in private consumption	0.25
σ_{ef}	Energy in private consumption	0.4
σ_{l}	Leisure—material consumption	1.0*

*Should be calibrated in the future work using price elasticities of supply for hydro, nuclear and wind electricity production and the compensated and uncompensated labor supply elasticity respectively.

Appendix 2: Calculation of emissions embodied in interregional trade

The method we apply for calculating the emissions embodied in interregional trade is similar to the one suggested by Böhringer, Rutherford, and Carbone in their NBER (2011) article (http://www.nber.org/papers/w17376). Unlike the recursive solution algorithm they use, we are solving the square system of equations to calculate the total embodied carbon intensity using the CONOPT solver (http://www.gams.com/dd/docs/solvers/conopt.pdf).

Appendix 3: Economic impacts by province

Table A2. Percentage changes in welfare as measured by equivalent variation of income

EV (%)	pap_r	pol_r	cap_r	shr_r	pap_n	pol_n	cap_n	shr_n
ANH	-1.21	-1.20	-1.19	-1.14	-1.09	-1.07	-1.04	-1.06
BEJ	-2.72	-2.80	-10.47	-3.79	-2.28	-2.30	-4.70	-3.49
CHQ	-2.91	-2.88	-5.94	-3.93	-2.67	-2.65	-3.72	-3.19
FUJ	0.09	0.05	-2.21	-0.68	0.07	0.04	-0.97	-0.45
GAN	-0.72	-0.49	1.51	0.47	-1.46	-1.27	0.99	-0.24
GUD	-0.46	-0.60	-0.89	-0.46	-0.37	-0.45	-0.38	-0.38
GXI	0.05	0.12	0.14	0.25	0.03	0.10	0.54	0.29
GZH	0.79	0.86	1.12	1.10	1.72	1.86	3.54	2.63
HAI	-1.49	-1.13	-32.95	-6.55	-1.33	-1.05	-4.45	-2.89
HEB	-0.43	-0.47	1.60	0.34	-0.61	-0.66	0.96	0.17
HEN	-0.94	-0.88	0.80	-0.32	-0.77	-0.75	-0.09	-0.43
HLJ	-4.75	-4.54	-4.88	-4.45	-4.30	-4.20	-4.01	-4.16
HUB	0.68	0.69	1.09	0.96	1.13	1.15	2.03	1.58
HUN	-1.52	-1.50	-1.60	-1.41	-1.45	-1.43	-1.31	-1.38
JIL	-0.85	-0.85	-1.07	-0.74	-0.74	-0.72	-0.37	-0.56
JSU	-0.33	-0.47	-1.79	-0.90	-0.14	-0.21	-0.83	-0.49
JXI	-0.90	-0.91	-1.63	-0.95	-0.70	-0.68	-0.64	-0.67
LIA	-1.52	-1.60	-0.62	-0.96	-1.38	-1.42	-0.66	-1.02
NMG	-3.81	-3.66	-1.89	-3.00	-3.62	-3.43	-1.19	-2.41
NXA	-1.96	-1.91	-3.83	-2.27	-1.81	-1.69	-2.12	-1.96
QIH	-0.46	0.27	0.20	0.31	0.58	3.03	6.37	3.47
SHA	-4.23	-4.26	-4.06	-4.09	-3.86	-3.84	-3.45	-3.65
SHD	-1.58	-1.69	-1.07	-1.45	-0.61	-0.65	-0.59	-0.60
SHH	0.11	0.04	0.25	0.31	-0.01	-0.08	0.07	0.03
SHX	-14.19	-14.44	-15.03	-14.26	-12.76	-12.71	-10.41	-11.59
SIC	-1.69	-1.77	-1.86	-1.62	-1.10	-1.13	-1.01	-1.05
TAJ	-2.36	-2.60	-4.85	-2.54	-1.77	-1.93	-1.82	-1.79
XIN	-3.94	-3.55	-4.85	-3.91	-3.49	-2.93	-2.99	-3.24
YUN	0.55	0.57	0.26	0.58	2.09	2.12	3.35	2.72
ZHJ	-1.14	-1.20	-16.84	-3.02	-1.00	-1.06	-4.04	-2.52
Eastern	-0.87	-0.96	-3.64	-1.20	-0.63	-0.69	-1.14	-0.89
Central	-2.26	-2.23	-1.90	-2.00	-1.96	-1.92	-1.29	-1.63
Western	-1.50	-1.44	-1.79	-1.43	-1.01	-0.89	-0.40	-0.70
CHN	-1.36	-1.39	-2.84	-1.46	-1.06	-1.06	-1.05	-1.06

Table A3. Percentage changes in GDP

GDP (%)	pap_r	pol_r	cap_r	shr_r	pap_n	pol_n	cap_n	shr_n
ANH	-0.88	-0.87	-0.90	-0.82	-0.73	-0.71	-0.66	-0.69
BEJ	-0.98	-1.01	-2.81	-1.22	-0.79	-0.80	-1.51	-1.15
CHQ	-0.96	-0.97	-2.09	-1.25	-0.77	-0.76	-1.23	-1.00
FUJ	-0.03	-0.04	-0.81	-0.28	-0.02	-0.03	-0.36	-0.19
GAN	0.23	0.29	0.76	0.50	0.91	1.01	2.16	1.53
GUD	-0.29	-0.35	-0.57	-0.29	-0.22	-0.25	-0.21	-0.22
GXI	-0.28	-0.26	-0.29	-0.21	-0.25	-0.22	0.02	-0.12
GZH	0.36	0.42	0.86	0.66	0.88	0.98	2.10	1.49
HAI	-0.82	-0.69	-12.01	-2.76	-0.72	-0.60	-2.07	-1.40
HEB	-0.15	-0.16	0.43	0.05	-0.18	-0.19	0.33	0.07
HEN	-0.29	-0.26	0.35	-0.08	-0.23	-0.22	0.06	-0.08
HLJ	-1.49	-1.47	-1.76	-1.43	-1.45	-1.41	-1.30	-1.38
HUB	0.14	0.14	0.45	0.34	0.40	0.42	0.89	0.65
HUN	-0.93	-0.93	-1.00	-0.86	-0.78	-0.76	-0.67	-0.72
JIL	-0.57	-0.58	-0.76	-0.52	-0.37	-0.35	-0.12	-0.25
JSU	-0.24	-0.28	-0.76	-0.42	-0.13	-0.15	-0.31	-0.22
JXI	-0.57	-0.57	-0.80	-0.56	-0.43	-0.41	-0.36	-0.39
LIA	-0.43	-0.46	-0.18	-0.26	-0.38	-0.40	-0.08	-0.23
NMG	-1.40	-1.35	-0.52	-1.08	-1.31	-1.24	-0.48	-0.89
NXA	-0.93	-0.91	-1.51	-0.99	-0.80	-0.75	-0.89	-0.84
QIH	1.41	0.71	-0.29	0.59	3.35	4.28	5.59	4.47
SHA	-1.79	-1.80	-1.76	-1.74	-1.59	-1.58	-1.38	-1.49
SHD	-0.29	-0.31	-0.27	-0.25	-0.16	-0.17	-0.13	-0.14
SHH	-0.16	-0.19	-0.12	-0.07	-0.14	-0.17	-0.10	-0.12
SHX	-5.36	-5.48	-6.10	-5.59	-4.78	-4.76	-3.90	-4.34
SIC	-0.86	-0.88	-1.02	-0.83	-0.67	-0.69	-0.59	-0.63
TAJ	-0.72	-0.78	-1.50	-0.77	-0.50	-0.55	-0.50	-0.50
XIN	-1.64	-1.51	-1.89	-1.61	-1.35	-1.11	-1.11	-1.23
YUN	0.01	0.04	0.03	0.10	0.86	0.88	1.61	1.23
ZHJ	-0.38	-0.40	-5.30	-0.92	-0.32	-0.34	-1.25	-0.78
Eastern	-0.32	-0.35	-1.27	-0.43	-0.24	-0.26	-0.39	-0.32
Central	-1.05	-1.04	-0.92	-0.94	-0.88	-0.86	-0.54	-0.71
Western	-0.69	-0.69	-0.85	-0.67	-0.37	-0.31	-0.03	-0.20
CHN	-0.56	-0.57	-1.12	-0.59	-0.42	-0.42	-0.38	-0.40

Appendix 4: Permit transfers in the ETS scenarios by province

Table A4. Value of permit transfers in billion USD; negative numbers indicate purchases, positive numbers sales; the table is sorted from greatest purchases to greatest sales.

Region	pap_n	pol_n	cap_n	shr_n
ZHJ	0.122	0.059	-2.774	-1.324
JSU	-0.465	-0.553	-1.240	-0.852
BEJ	-0.073	-0.082	-1.144	-0.608
GUD	-0.501	-0.632	-0.552	-0.526
SHD	-0.558	-0.596	-0.502	-0.530
FUJ	0.085	0.071	-0.428	-0.171
CHQ	-0.025	-0.018	-0.313	-0.169
HAI	-0.020	0.002	-0.250	-0.135
SIC	-0.259	-0.277	-0.208	-0.233
SHH	-0.273	-0.320	-0.182	-0.227
HLJ	-0.138	-0.104	-0.053	-0.095
NXA	-0.005	0.001	-0.019	-0.012
TAJ	-0.023	-0.054	-0.018	-0.020
ANH	-0.025	-0.015	0.003	-0.011
JXI	0.016	0.022	0.035	0.026
GXI	-0.076	-0.053	0.100	0.012
SHA	-0.019	-0.012	0.103	0.042
JIL	0.053	0.062	0.196	0.125
HEN	-0.286	-0.269	0.199	-0.043
LIA	-0.213	-0.238	0.202	-0.005
HUN	0.152	0.163	0.216	0.184
XIN	0.200	0.310	0.294	0.247
QIH	0.095	0.184	0.307	0.201
HEB	-0.412	-0.444	0.506	0.046
SHX	0.032	0.045	0.606	0.318
NMG	0.076	0.127	0.723	0.398
GAN	0.406	0.435	0.772	0.588
GZH	0.563	0.596	0.975	0.769
YUN	0.790	0.798	1.181	0.985
HUB	0.780	0.791	1.261	1.020
Eastern	-2.329	-2.789	-6.381	-4.352
Central	0.660	0.823	3.188	1.923
Western	1.669	1.966	3.194	2.430