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UNIVERSITE LILLE 1 - SCIENCES ET TECHNOLOGIES

FACULTE DES SCIENCES ECONOMIQUES ET SOCIALES

ECOLE DOCTORALE SESAME

AN ECONOMIC AND POLITICAL ASSESSMENT OF CARBON PRICING POLICIES IN CHINA

(UNE EVALUATION ECONOMIQUE DES POLITIQUES DE FIXATION DU PRIX DU CARBONE EN CHINE)

Thèse

pour l'obtention du grade de
Docteur en Sciences Economiques

présentée et soutenue publiquement par

Xin WANG

Le 4 novembre 2011
devant le jury composé de

Alain AYONG-LE-KAMA, Professeur à l'Université Lille 1 - Sciences et Technologies, Directeur de thèse

Dominique BUREAU, Délégué Général du Conseil Economique pour le Développement Durable (CEDD), Ministère de l'Ecologie, du Développement Durable, des Transports et du Logement (MEDDTL)

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Abstract

China's approach to tackle climate change has been marked by a rapid shift toward market-based instruments; particularly the carbon pricing policy since its twelfth Five Year Plan (FYP) (2011-2015) was launched. Carbon prices were indirectly generated by the massive use of export VAT refund rebate and export tax on energy-intensive products since 2007. It will be explicitly complemented by an emission trading scheme (ETS) tested at provincial level by 2013 and implemented at national level by 2015. While one could expect such initiatives to grant China a status as a "climate-champion", doubts have been cast on the rationale for taxing energy-intensive exports on the one hand, and the value given to CO2 either at the border or domestically on the other. By using both quantitative and qualitative assessments, the thesis contributes to unpacking China's domestic and border carbon pricing policies by analyzing their incentives and domestic and global consequences. It proposes first to accelerate domestic carbon price stringency; and second to implement an explicit and comparable (20$/tCO2) export carbon price, particularly on energy-intensive products, as a short-term transitional measure before a domestic comparable carbon price is introduced.

Résumé

Les approches chinoises pour la lutte contre le changement climatique se sont orientées vers les instruments économiques. En particulier, la tarification du prix du carbone serait mise en oeuvre durant la période de son 12e plan quinquennal (2011-2015). Les prix implicites du carbone sont aussi engendrés par l'usage massif de l'abattement de TVA et les taxes à l'exportation des produits intensifs en carbone depuis 2007. Ceci serait complété par une mise un oeuvre par un marché d'échanges des permis d'émissions ici 2015. Cependant, l'un pourrait anticiper ces approches un statut de champion pour la Chine, les doutes s'émergent à la fois sur la motivation de taxer l'exportation des produits intensifs en carbone et sur les prix donnés au carbone au marché domestique et à l'export. En utilisant les approches quantitatives et qualitatives, cette thèse examine les impacts des prix du carbone en Chine et leurs conséquences à l'échelle globale. La thèse propose d'abord d'accélérer la mise en oeuvre du prix du carbone au marché domestique et ensuite introduire un prix du carbone explicite (20$/tCO2) à l'export comme une mesure de transition avant que le prix du carbone atteigne un niveau comparable.

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The achievement of this thesis is accompanied by great supports of the following persons and institutes while I am of sole responsibility. I would like to thank Professor Alain Ayong Le Kama for having accepted to supervise this thesis. His suggestions, critiques and guidance have made important contributions to the thesis.

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Finally, the thesis cannot be done without the support and encouragement of my parents, friends and particularly my beautiful wife Jiayi who has accompanied and inspired me during the entire thesis.

Contents

General Introduction[1]

1. Introduction

Climate change has become one of the major threats to the development of mankind in the twenty-first century. Emissions of the Green House Gases (GHG) engendered by anthropogenic activities are considered major contributor to the global warming in recent decades. According to the fourth assessment report of the Intergovernmental Panel on Climate Change (IPCC), "[m]ost of the observed increase in global average temperatures since the mid-20th century is very likely due to the observed increase in anthropogenic GHG concentrations" (IPCC, 2007). Such statement has leveled the importance of taking immediate measures for addressing the climate change. So far, the international climate change negotiation conducted under the framework of the Kyoto Protocol which is a fruitful result of United Nations Framework Convention of Climate Change (UNFCCC) has reached to an agreement on the level of the safety valve for mankind from suffering destructive and irreversible climate damages: to limit the increase of planet temperature below two degree by 2050[2] based on 1990 level. However, the current national pledges of GHG emission reduction efforts by 2020 which have been submitted to the UNFCCC by its country members could hardly ensure the two degree target (Jotzo, 2011; Rogelj et al., 2010). In addition, the Kyoto Protocol which sets mandatory GHG emissions reduction targets for developed countries grouped as Annex I will expire by 2012. The agreement of an effective international treaty for the following period seems to be unclear, thus leaving the achievement of the two degree target at stake. In the logic of taking immediate actions to minimize the cost due to climate change damage (Stern, 2007), more global efforts must be done in order to prevent lock-in effects and to attain the long-term climate change targets.

Among key elements which ensure a successful consolidation of international efforts, **mutual trust**[3] (State Council Information Office, 2008), **transparency** (McKibbin and Wilcoxen, 2002; Transparency International, 2011) and **incitation** effects (De Boer, 2007) can be considered indispensable for each country. First, the mutual trust requires understanding objectives, interests and difficulties of each country. Second, the policy transparence (and the measuring of policy effects not in an invasive way) consolidates such reciprocal confidence and provides credible basis for making next-step actions. Finally, the incitation effect of a climate policy could generate

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[1] This chapter contains two published papers:
Voituriez, T., Wang, X., 2011, Getting the carbon price right through climate border measures: a Chinese perspective, ***Climate Policy***, 11, pp.1257-1261.
Wang, X., Chen, Y, 2010, Disentangling border carbon tax – an analysis of the EU policy, ***Chinese Journal of European Studies***, 166, pp. 44-58. (in Chinese)

[2] Equivalent to maintaining the 450 ppm CO_2-eq

[3] See Hu Jintao's speech "Mutual trust is key for collaborating with China", available at http://blog.appliedmaterials.com/mutual-trust-key-collaborating-china, 2011; Also see China Daily, "Beijing urges more political mutual trust", 18 April, 2011, available at http://www1.chinadaily.com.cn/china/2011-04/18/content_12345023.htm

further implementations of actions of other countries, thus contribute to strengthening global mitigation efforts.

The need of immediate actions for addressing climate change is not an exception and is even more urgent in China facing domestic and international contexts. China is now encountering both potential energy shortages and challenges related to climate change. China would suffer slightly higher negative impacts of climate change than the global level (NDRC, 2007). It is currently the biggest CO_2 emitter in the world and its CO_2 emissions could continue to increase with an annual growth rate of 2.8% during 2006-2030, compared to 0.1% for OECD European countries over the same period (EIA, 2009). Its energy deficiency in terms of coal and natural gas could reach 25% of total domestic production, while its oil import dependency could attain 60% by 2020 (Mao and Chen, 2008). **It is not possible for China to replicate the development pathways of industrialized countries and wait for the peak of its Kuznets curve to reduce its CO_2 emissions** (Tubiana and Wang, 2011). Instead, its modernization trajectory must coordinate economic growth with GHG emissions control (He et al., 2010). Obviously, combating climate change is certainly in China's own interest, a realization that has helped the development of a political willingness to tackle the problem.

> *"We should make our endeavor on climate change a win-win for both developed and developing countries and a win-win for both the interests of individual countries and the common interests of humanity."* (Speech given by President Hu Jintao of China to the United Nations General Assembly, 23 September, 2009[4])

> *"A comprehensive plan and policy guidance shall play their roles in coordinating economic development and climate change mitigation, domestic needs and international situations, as well as current needs and long-term interests."* (Speech given by China's Climate Change Minister Xie Zhenhua, January 9, 2010[5])

> *"Developing low carbon economy corresponds to China's own interest and follows the development trend of the world."* (Zhou Shengxian, China's Environmental Protection Minister, 2008)

Such willingness has been concretely translated into setting a long-term strategy of developing the low carbon economy (LCE) in its 12th Five Year Plan (FYP) (2011-2015) which aims to **reorient China's market toward larger components of products with higher value-added and technology contents and lower pollution and energy and carbon intensities**. However, most of China's current policies are

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[4] See http://www.nytimes.com/2009/09/23/world/asia/23hu.text.html for the whole speech.

[5] See http://www.chinafaqs.org/library/xie-zhenhuas-speech-peking-university-guanghua-college-management-january-2010 for the whole speech.

command-and-controls which are **not cost-effective** in terms of GHG emissions reduction and energy savings and have gained China very **limited recognition at the international community** (Zhang, Z.X., 2010). Particularly, the lack of an explicit and comprehensive domestic carbon price has made China a principal target in the literature of carbon leakage and competitiveness given its large capacity of energy-intensive products (Gros, 2009). Despite the fact that the existence of carbon leakage and competitiveness problems have received so far mixed results (Elliott et al., 2010; Babiker and Rutherford, 2005), such issues do have real impacts: they constitute not only a barrier for developed countries to implement more stringent climate policies, but also a contentious subject between developed and developing countries which could lower the mutual trust and **slow the consolidation of making global climate efforts** (Droege, 2011; Wang and Chen, 2010).

In the light of either or both contexts, China has decided to implement more economic and market-based instruments in order to strengthen cost-effectively its efforts to develop LCE and/or contribute to consolidating international efforts for addressing climate change. Among such policies, export VAT rebate and export tax have been implemented massively since 2007 on energy- and carbon-intensive products. Domestic emission trading system (ETS) is on the official agenda and pilot programs could be implemented by 2013[6]. The research of carbon tax has also been conducted at ministerial level and is under consideration of short-term implementation (author’s interview). However, the absence of an explicit and predictable carbon price on the export on the one side and the uncertainty of the level and coverage of a domestic carbon price in the forthcoming years on the other side still constitute a challenge for China from becoming a “climate champion”.

By using both quantitative and qualitative assessments, this thesis contributes to unpacking China’s domestic and border carbon pricing policies. First, it analyzes the **incentives** of both **export taxation** and the **ongoing domestic carbon pricing policies** and examines their domestic and global impacts. Second, it provides policy recommendations on how to **introduce a** comparable, explicit and predictable **carbon price into China’s export as transitory measure** before that domestic carbon price reaches to a comparable level. Such analyses dedicate to enhancing policy comprehensiveness, to strengthening mutual trust and policy transparency and finally to consolidating global climate change efforts. This could not only contribute to an effective design of carbon pricing policies for LCE development in China, but also provide China a pro-active image and consolidate global climate change efforts, thus **making China’s carbon pricing policies a win-win strategy** as the President’s speech has mentioned.

This general introduction aims to demonstrate in a detailed manner both the

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[6] See http://green.sohu.com/20110627/n311763480.shtml, 27 June, 2011 (in Chinese). Also see See “China planning emissions trading in 6 regions”, April 11, 2011, http://af.reuters.com/article/energyOilNews/idAFL3E7FB1Q320110411

domestic and international contexts of implementing carbon pricing policies in China. It is organized as follows: Part Two, Three and Four explains **why there is a domestic willingness of implementing carbon pricing policies in China**. Part Two reviews briefly the level and drivers of energy consumption and CO_2 emissions in China and demonstrates China's policy orientation of developing LCE; Part Three examines the achievements and insufficiencies of major domestic policies; Part Four demonstrates the political firmness of implementing market-based instruments, particularly carbon pricing policies in China. Part Five and Six present **one of the major international challenges** of implementing carbon pricing policies for China, which is the **carbon leakage and competitiveness** issue: Part Five presents the carbon leakage and competitiveness problems under the presence of unequal carbon prices and analyzes the negative impacts of carbon leakage and competitiveness in terms of consolidating global efforts of addressing climate change; Part Six shows insufficiencies of current Chinese policies in terms of curbing carbon leakage. Finally, Part Seven concludes and introduces the subject and chapters of the thesis.

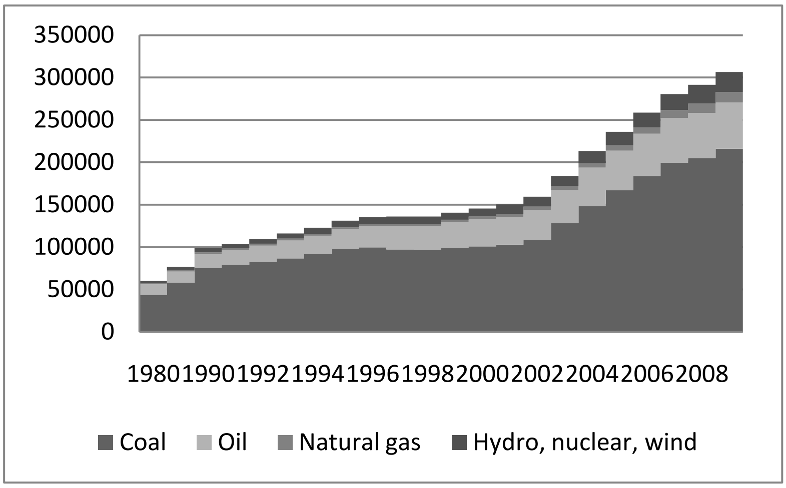
Domestic willingness of implementing carbon pricing policies in China

2. Review of CO_2 emissions and energy consumption and policy orientation

2.1 Climate and energy performance

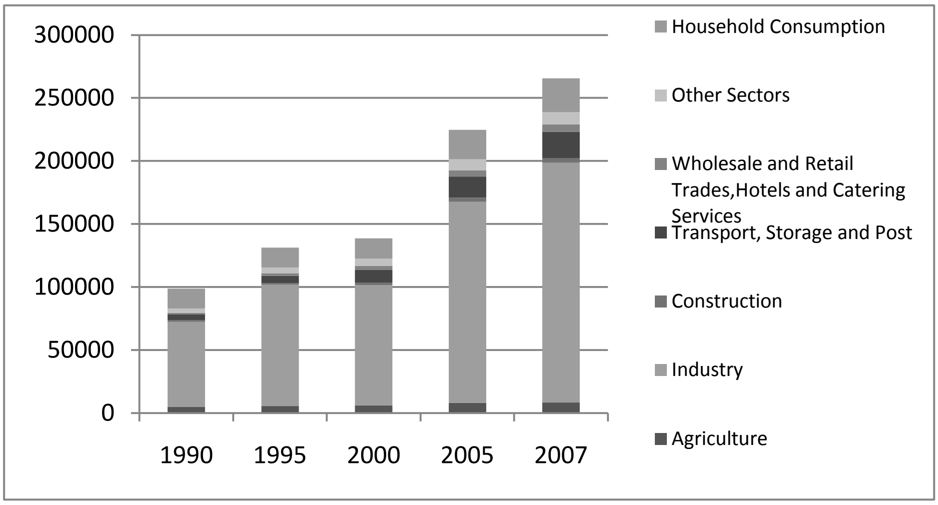
China's energy consumption increased dramatically during the last few years. As figure one shows, the major increase of total energy consumption comes from coal consumption, which will still be a dominant fossil fuel in the short future. At sectoral level, the industrial sectors (including energy sector) are the major driver of energy consumption increase of recent years (see figure two). However, **contrary to the total energy consumption increase, energy and carbon intensity decreased both at national and sectoral level**. Figure three shows that the energy intensity decreased importantly between 1980 and 2000 while started rebounding during the 10th Five Year Plan (FYP) (2001-2005) period majorly due to the increasing investment on energy-intensive sectors. The implementation of the energy intensity target during the 11th FYP (2006-2010) has then effectively dragged down the energy intensity. At sector level, the carbon intensity of both industrial and energy sectors has decreased during the period of 11th FYP despite the fact that their total sectoral CO2 emissions increased (figure four and five). Finally, this situation is similar at product level. As shown by figures six to nine, although the production of major energy-intensive products increased during the last couples of years, their energy intensity has achieved a perpetual decrease. For copper and aluminum products, their energy intensity has reached almost to the world advanced level by 2009. For crude steel and cement products, their energy intensity is approaching to the world advanced level by 2009.

Figure 1. Energy consumption by fuel types in China (unit: 10000tce)



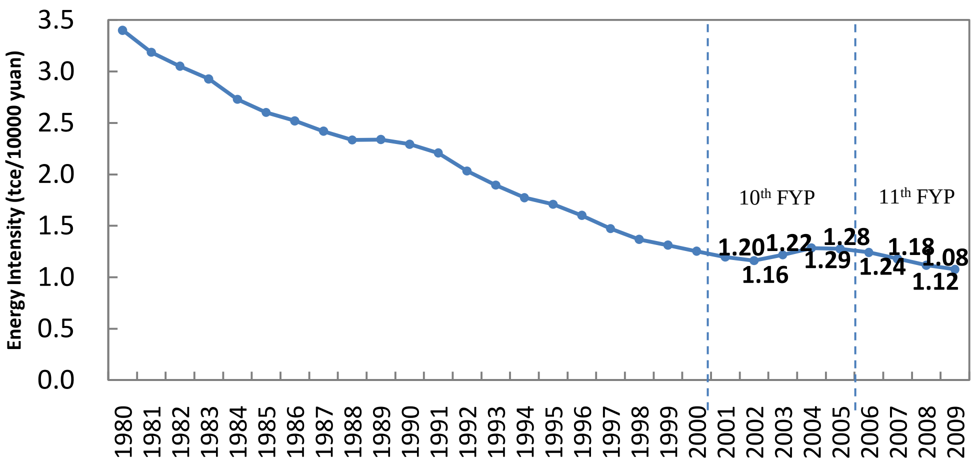
Source: 2010 Statistical Yearbook of China (SY), National Bureau of Statistics (NBS).

Figure 2. Sectoral energy consumption in China



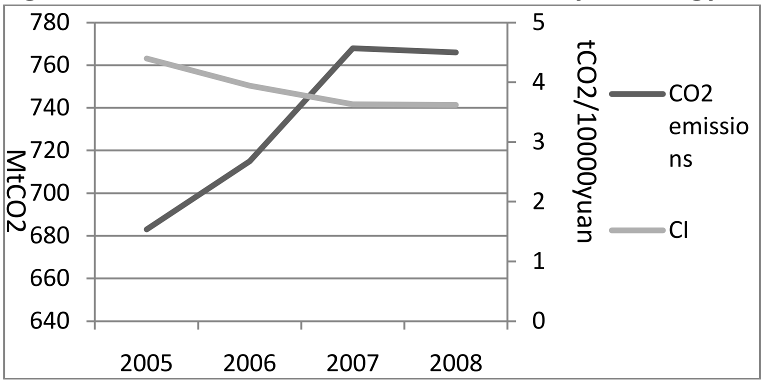
Source: 2010SY, NBS.

Figure 3. Energy intensity evolution in China: 1980-2009 (2000 constant GDP)



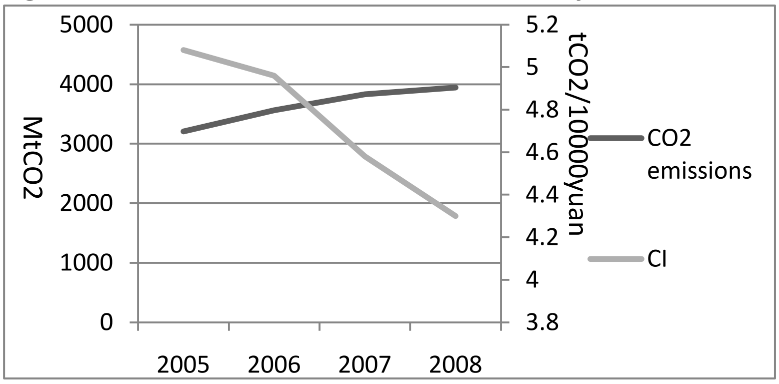
Source: 2010SY, NBS.

Figure 4. CO_2 emissions and carbon intensity of energy sector in China



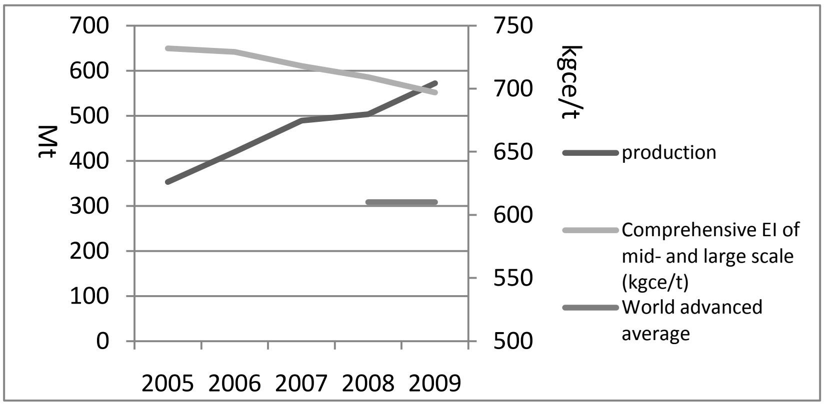
Source: Li (2011) based on related statistical data in China.

Figure 5. CO_2 emissions and carbon intensity of industrial sectors in China



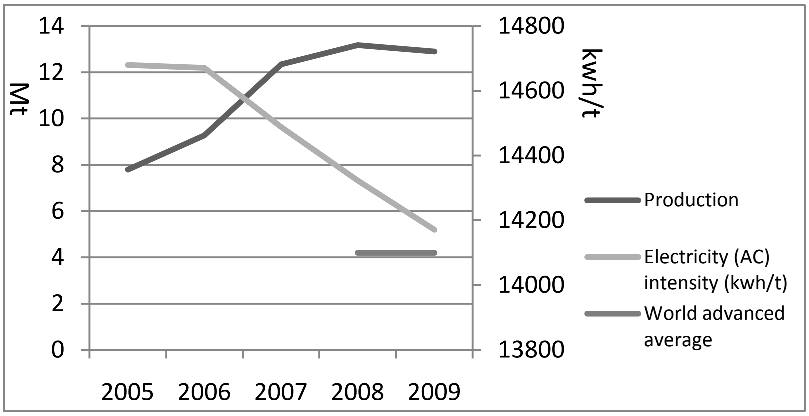
Source: Li (2011) based on related statistical data in China.

Figure 6. Crude steel production, energy intensity and world advanced average



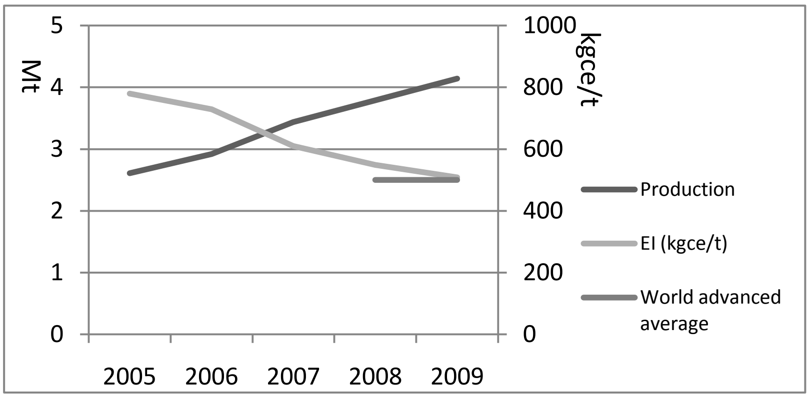
Source: Li (2011) based on related statistical data.

Figure 7. Aluminum production, electricity (AC) intensity and world advanced average



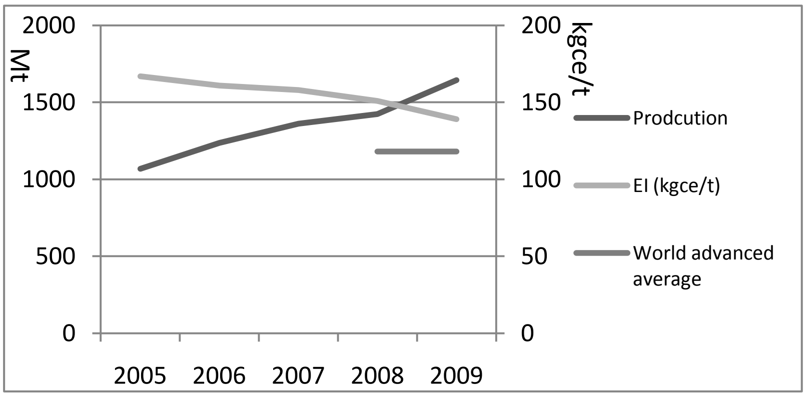
Source: Li (2011) based on related statistical data.

Figure 8. Copper production, energy intensity and world advanced average



Source: Li (2011) based on related statistical data.

Figure 9. Cement production, energy intensity and world advanced average



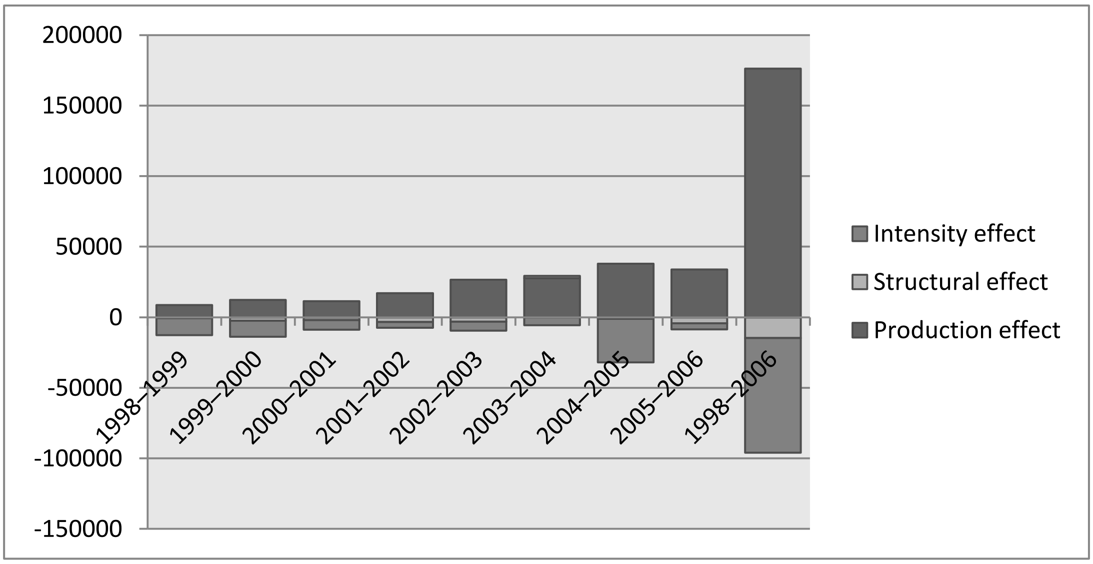
Source: Li (2011) based on related statistical data.

2.2 Policy orientation based on drivers of CO_2 emissions

The major contributors of energy consumption and CO_2 emissions change in China can be explicitly illustrated by using the decomposition analysis (Ang 2005, 2004; Ang and Zhang, 2000; Ang and Lee, 1994). Under such approach, it explains the change of total energy consumption or CO_2 emissions due to fossil fuel combustion by three contributors: scale or production effect explains, other things being equal, the energy consumption change due to output change of a sector or an economy; structural effect explains the contribution of structure change to energy consumption change other things being equal; the technique or intensity effect explains the change of energy consumption due to the per unit GDP energy consumption or CO_2 emissions changes other things being equal. In fact, many decomposition exercises have been conducted during the last couple of decades (for example, Liao and Wei, 2010; Zhang, Y., 2010; Zhao et al., 2010; Chai et al., 2009, etc.) and provided similar and convergent results of the contribution of different effects to total energy consumption or CO_2 emissions in China. For example, based on Zhao et al. (2010), figure ten shows that structural and intensity effects have led to a reduction of total industrial energy consumption during 1998-2000. However, the total energy consumption increase since 2000 was significantly driven by the production effect which compensated the decrease of structure and intensity effects and led to net energy consumption increase during this period.

The decomposition analysis clearly shows how policy could be oriented to reduce energy consumption and CO_2 emissions which could be achieved by restructuring the economy, increasing the energy efficiency and lowering GDP growth rate. Indeed, this LCE strategy has been perfectly understood by the central government. Such political intention is addressed in the 11th FYP (2006-2010) and 12th FYP (2011-2015): to **slow the economic growth** (scale effect); to **structure the economy** toward larger contents of products with higher value-added and advanced technology and lower share of energy-, resource- and pollution-intensive sectors (structural effect) and finally to **abate energy and carbon intensities** (intensity effect).

Figure 10. Decomposition of China's industrial energy consumption: 1998–2006 (10,000 tce).



Source: Zhao et al. (2010).

3. Achievement and insufficiencies of current domestic policies

3.1 Major domestic policies

In order to achieve the strategic development dynamic of LCE, China has introduced for the first time mandatory targets into the 11th FYP (2011-2015)[7]. The environmental concerns, particular the energy and climate policies among such mandatory targets have constituted the center of these mandatory targets. Such willingness of developing a LCE has been prioritized in the 12th FYP (2011-2015). Not surprisingly, the 12th FYP has made further steps on climate change policies: it introduced carbon intensity target[8] as a mandatory target together with energy intensity as well as other climate-energy targets. In this section, we highlight four principal types of policies and examine the shortage of these command-and-control policies encountered during the 11th FYP (2006-2010).

3.1.1 What a "mandatory target" means in China: binding official's performance evaluation to target achievement

In order to ensure the achievement of its energy efficiency target of the 11th FYP, the Chinese central government has implemented a mechanism which allows the higher level administrator assigning responsibility to the lower level officials. Details are presented by three plans published by the State Council on November 17, 2007[9]. These plans outline that higher level officials sign a "contract" which indicates a certain energy saving target within a period with lower level officials. The higher level official will examine the results of the achievement of energy performances of the regions of lower level officials. For those who fail to obtain the energy saving target signed in the "contract", the official cannot participate to performance evaluation of that year, therefore would not be promoted regardless of the degree of other economic and social targets achievement. The "contract" has been established at central-provincial level and then broken down respectively to provincial-city, city-town until town-county level. Such "contract" has also been established among officials and responsible of state-owned firms.

This mechanism has been well applied to the shutdown policies of small and inefficient installations. For example, the *Suggestions of the State Council on the Acceleration of Shutting down Small and Inefficient Thermal Power Plants* (Guo Fa (2007) No.2), published in early 2007 and the *Notice of the State Council of Consolidating the Task of Shutting down Small and Inefficient Industrial Installations* in April 2010 (Guo Fa (2010) No.7) have clearly demanded using such responsibility binding "contract" to ensure the implementation of shutdown policy.

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[7] Precedent FYPs only made anticipated directive targets with no engagement and enforcement mechanism on the target achievement

[8] To reduce 17% carbon intensity by 2015 based on 2010 level.

[9] They are respectively Plan of the implementation of unit GDP energy consumption statistics, Plan of the measuring of unit GDP energy consumption and Plan of the implementation of evaluation of unit GDP energy consumption.

This mechanism of linking directly the promotion opportunity of officials to the energy saving target aims to provide strong incentive for local governors to strengthen the efforts of increasing energy efficiency, thus contributing to reducing CO_2 emissions. In addition, such mechanism has linked the performance evaluation of a higher level official to the target achievement of lower level officials. For example, whether the province leader can participate to his performance evaluation depends on whether the energy efficiency targets can be achieved at the city level. The provincial leaders thus tend to use enforcements to officials at city level in order to achieve the energy efficiency target[10].

3.1.2 Tightening market entrance criteria

Another important measure of curbing the energy intensity in China is the implementation of strict market entrance criteria of EI sectors. In December, 2005, the *State Council released the Provisional Decision on Accelerating Structure Adjustment* (Guo Fa (2005) No.40). The Decision has provided the orientation of sector restructuring toward an economy composed by higher per product value-added and lower level of pollution and resource extraction. Concretely, the development of different sectors has been defined:

1). Strengthen and consolidate the basic position of agricultural sector and transform from conventional agriculture to modernized agriculture.
2). Strengthen the infrastructure construction and related basic industries development, strengthen the supply to economic growth and social development.
3). Developing majorly the manufacturing sectors with advanced technology levels and ensure the important role to economic development.
4). Accelerating the development of advanced technology sectors and strengthening its contribution to economic growth.
5). Stimulating the development of service sectors and increasing their market share to total GDP.
6). Prioritizing the development of circular economy and accelerating the development of energy-saving and environmental friendly society.
7). Structuring and optimizing regional economy.
8). Balancing domestic development and globalization in order to contribute to market restructuring.

Such priorities confirm actually two things which illustrate **the current Chinese development dynamic**: firstly, the **willingness of reducing energy consumption and energy intensity** has been clearly demonstrated; secondly, **the need of energy-intensive products** (which would be produced with higher energy efficiency) for infrastructure as well as other basic economic development needs **would probably persist and would be majorly satisfied by domestic capacity** (see item 2

[10] See for example, "A Mayor of Zhejiang Province warns the energy efficiency officials: your demission would be before mine", available at http://news.sohu.com/20100926/n275260025.shtml (in Chinese).

above).

The *Directory Plan of Sector Restructuring* has been published annually since 2005 in order to indicate whether a specific investment is promoted, limited or prohibited. For example, the 2005 version of the *Directory Plan* includes more than twenty sectors where 539 investments are promoted, 190 investments are limited and 399 investments are prohibited. The *Energy Saving Law* (revised version of January 2007) has also clearly required establishing energy saving evaluation and analysis on all investments with fixed capital in order to curb the expansion of EI investments that failed to satisfy current energy saving standards. The *General Plan of Energy Saving and Emissions Reduction* published on June 3, 2007 by the State Council has then clarified the use of loan and land authorizations as major instruments and set specific regulations for limiting the growth of energy-intensive sectors. The authorization of new investments has also been assigned to inter-institutional taskforce and a responsibility mechanism which link the official performance evaluation to whether the energy efficiency standards of new investments satisfy current standards has been established. The authorization of new investments is therefore under six constraints:

1). Market entrance standard of the sector
2). Investment authorization verification or record
3). Pre-authorization of land use
4). Environmental impact assessment
5). Energy saving assessment
6). Loan, security and urban planning standards

where the environmental and energy concerns dominate. Finally, in order to ensure a good implementation of energy saving and environmental impact assessment of new investment, the NDRC has published the *Provisional Regulation of the Assessment and Verification of Energy Saving of New Investments on Fixed Assets* on September 17, 2010. The Regulation has therefore strengthened and accentuated the imperative of using energy saving assessment and verification as a veto to authorize fixed assets investments which fail to satisfy the energy saving standard and requirements.

3.1.3 Pricing policy as governmental regulation

During the period of 11^{th} FYP (2006-2010), China has also adopted price policies on energy-intensive sectors and green sectors in order to accelerate the green economy transformation. Among such policies, two major policies have been implemented in a large scale. First, the export VAT refund rebate and/or export tax on energy-intensive products have been massively implemented. By refunding less or zero VAT at the export of energy-intensive products relative to other products, such method introduces higher cost on the export of energy-intensive products. Detailed presentation will be made in Chapter Five. Second, a discriminative electricity price on energy-intensive sectors has been introduced since 2007. The *Notice on*

Consolidating the Implementation of Differentiated Electricity Prices published in September, 2007 (Ga Gai Jia Ge (2007), No.2655) has required local governments to divide firms into promoted, limited and prohibited categories in accordance to *Directory Plan of Sector Restructuring* mentioned above, and suppress gradually the preferential electricity prices on energy-intensive firms. However, after the outburst of global economic crisis and the reduction of export VAT refund, certain provinces have provided preferential electricity price for energy-intensive sectors. In such regard, the *Notice on Cancelling the Preferential Electricity Price of Energy-Intensive Firms* which was published in May, 2010 (Fa Gai Jia Ge (2010), No.978) has required to cancel all preferential electricity prices to energy-intensive firms after the economic crisis at certain local levels. The Notice has strengthened the cancelation of preferential electricity price to major energy-intensive sectors and the use of punitive (higher) electricity price to firms of which the energy intensity level is higher than the benchmark.

3.1.4 Governmental subvention and encouragement

In order to lessen the local resistance to and the impact of shutdown policies, the *Notice of the Distribution of the General Plan of Energy Saving and Emissions Reduction*, published by the State Council in 2007 (Guo Fa (2007), No.15) has provided a provision of establishing special fund at central governmental level to compensate the loss due to the shutdown of energy-intensive firms in regions with lower economic development level. Later, the Ministry of Finance published the *Provisional Regulation of the Management of Central Fund for the Elimination of Backward Capacities* in December, 2007 (Cai Jian (2007), No. 873). The Regulation indicates that the central government will transfer a proper amount of money in accordance to the closed capacities of energy-intensive sectors to local governments of the region with lower economic development level.

3.2 Achievement and drawbacks of command-and-control policies

As seen, **the energy saving and climate change mitigation policies in China are majorly composed by command-and-control policies**. Most of current pricing policies (as part 3.1.3 above has mentioned) are given in a regulatory form which does not really give explicit carbon price signal[11]. The reason of the dominance of command and control policies in China is two-fold. First, the market of production factors, particularly energy and certain natural resources market is not mature despite the fact that general reform has been introduced to liberalize energy market in China (Ma, 2011). The scarcity of such resources is dampened by the government price regulation and therefore, the market cannot plays effectively to reduce negative environmental externalities. Second, the innovative introduction of energy intensity target as a mandatory policy in 2006 did not leave sufficient time for the Chinese government to implement cost-effective market-based instruments to attain the target (Yu et al., 2011).

[11] Of course, there exist subsidies, price differentiations, etc. which play based on the economic ground in China. Specific policies are available at www.gov.cn as well as websites of related administrations.

Command and control policies are not cost-effective measures although they could achieve quickly a certain objective. This seems to be true in the real world for China. Debates on the efficiency and the cost of major command and control policies, namely the shutdown policy and the linking of responsibility to official's performance evaluation have been frequently raised in recent years in China. A demonstration of the real problems that these command-and-control policies encountered in China during the 11th FYP period can be helpful for understanding why there is a need of implementing more market-based instruments.

3.2.1 Problems of shutting down small electricity plants

The shutdown of small and inefficient thermal power plants has achieved a significant result in terms of energy- and carbon intensity abatement. During the first four years of the 11th FYP plan period (2006-2010), the accumulated capacity which has been shut down has obtained 60.37 Mn Kw given that the anticipated total shutdown capacity for the 11th FYP plan period is 50 Mn Kw. However, the regulation policy has generated debates not only on **policy efficiency** but also on **equity** (fairness) which is a predominant issue in regional development policy in China (Dong et al., 2011). First, the efficiency debate is based on the shutdown policy on thermal power plants with a unit capacity around 125-200 Mw (briefly named "small plants" in this section thereafter). Those small plants are all listed to be shut down while for certain plants among these small plants, the shutdown policy would generate inefficiency problem and would not generate net welfare amelioration although the carbon and energy intensity could also be abated. Specifically, these inefficiency issues can be concluded as follows:

1). Recently constructed small plants. Chinese policy of small plants construction was relatively loosened between 2000 and 2006. The electricity supply shortage behind the fast economic growth during that period has led to a result of a significant presence of recently constructed small plants in China. If those plants are (or have been) closed, the short life cycle could be considered a waste.

2). Electricity grid peak/valley adjustment. The existence of a certain amount of small plants is important to the peak/valley electricity transport adjustment for local grids and contributes to energy saving. If all small plants are closed and replaced by super- or hypercritical plants which do not fit to the peak/valley adjustment parameter of the grids in China, this would reduce the efficiency of electricity transport.

3). Small electricity-heat cogeneration plants. If these plants are shut down and the replacing plants do not provide electricity-heat cogeneration function, new heat supply facilities would be required, particularly in the northern part of China. This reduces the policy efficiency.

4). Own small plants of big energy-intensive firms. The own small plants of big energy-intensive firms are usually not efficient individually while contribute to increasing the energy efficiency at firm level since the electricity can be generated from waste heat and pressure of such energy-intensive firms (steel, cement, etc.). The shutdown of such own small plants would therefore reduce the efficiency at firm level and could reduce the total efficiency of such policy.

Second, the equity and fairness issue is based on the fact that the shutdown policy is accompanied by the authorization of construction of new large scale thermal power plants. The current policy demands that the authorization of new installations of large-scale thermal power plants must be preconditioned on the shutdown of small plants. Major debates on the fairness and equity issue can be summarized as follows:

1). Equity issue on big and small electricity generation firms. For the big five state-owned electricity generation company, the shutdown policies enable them to apply for new installations of large scale electricity plants. The shutdown policy therefore provides an opportunity for them to expand their market size. However, for small electricity generation firms which do not possess sufficient capital to construct large-scale thermal plants, the shutdown policy becomes rather a punition for them.

2). Equity among regions. The small plants could be shut down in one region and the new installation of large-scale plants does not necessarily locate to the same region. This could generate artificially regional difference on electricity output which could affect economic development for regions with electricity deficit.

3). Unemployment. As mentioned above, the unemployment due to the shutdown of small plants cannot be totally absorbed in the short term which brings social tension to local governments. According to the estimation of Pan et al. (2009), the shutdown policy of small plants during the period of 2006 and the first half of 2010 could generate a net amount of unemployment of 396 000 posts.

3.2.2 Limits of using target responsibility binding policy (mandatory policy)

Another example of the ineffectiveness of regulation policy in China is the linking of official's performance evaluation to energy saving and climate change mitigation targets, which is demonstrated in part 3.1.2 above. Under such a mechanism, the province and city leaders play majorly a role of supervisor and the leaders at town and county levels are usually the "executive" manager of energy and climate targets. However, the lower the administrative level, the lower the capacity and the fewer the financial source could be used to attain the targets. This lack of savoir-faire has led to extreme electricity shutdown on firms and even on those which have already achieved their assigned energy saving target at the end of 2010 at certain provinces in order to achieve the target[12]. Other extreme cases can be found massively at the end of 2010 at city and town level where the achievement of energy-intensity target is not optimistic. For example, the Anping town of Hebei province has cut the electricity supply of the whole town which caused the non-functioning of electricity and water supply of household and even for hospital and traffic lights, at the end of 2010 in order to achieve its energy saving target[13]. Similarly, some cities or towns in the northern part of China have stopped the heating supply by the end of 2010 in order to assure their energy saving targets[14].

In fact, **the binding responsibility mechanism dismisses incentives for officials to make pro-active measures to increase energy efficiency**. The performance evaluation of an official depends on a very large degree of the GDP performance once the energy target is achieved. To the contrary, the total performance evaluation result will be poor if the GDP target is not attained no matter how good the energy saving target is. This can be reflected by the reporting of provincial GDP and energy saving targets. Most of the energy intensity targets that each province provided initially lay below or are equal to the national target level. The central government had to enforce allocating higher targets for provinces providing lower energy saving targets. To the contrary, most of the GDP targets initially provided by provinces are higher than national target level and the central government had to lower the provincial GDP targets (Ma and Li, 2011). Similar situations can also be observed inside a province when assigning energy intensity targets to city level. From this perspective, the incentive for local leaders to implement effective energy efficiency measures is low and compromised by the development of GDP.

4. Political willingness of implementing more economic instruments

The lack of incentive and cost-effectiveness of the current command-and-control policies has in fact been reminded by many studies or advisory reports (Ye and Weizsacker, 2009) and has drawn great attention at the central government. In State Council's *Notice of the Publication of the Plan of Environmental Protection of the 11th FYP* (Guo Fa (2007), No.37), the importance of using more market-based instruments for protecting the environment has been accentuated: the environmental policies should "be restructured to legislative, economic and technique instruments with additive command-and-control policies when necessary instead of the use of the latter as major environmental policy" and "the reform of resource tax, consumption and import/export tariffs should completely integrate environmental concerns in order to establish ultimately a complete environment taxation system to support the development of energy-saving and environmental friendly society".

Moreover, **the official pronunciation of the need and the urgency of using economic instruments for environmental concerns in China is not occasional but perpetual in**

[12] See http://news.cn.yahoo.com/ypen/20100920/28037.html (in Chinese)
[13] See http://money.163.com/10/0906/23/6FUG545U002524SO.html (in Chinese)
[14] See http://news.cn.yahoo.com/ypen/20101129/104017.html and http://news.cn.yahoo.com/ypen/20101022/57100.html (in Chinese)

recent years. Such need has been frequently pronounced during Communist Party's meetings. For example, the December 2007 *Communist Party's Central Committee Conference on Economic Issues* has clearly demanded a "speeding up in the implementation of fiscal, pricing and financial policies to save energy and reduce CO_2 emissions". Similar sentences can also be read by each year's *Government Activity Report*, China's white papers on energy and climate change as well as the *Annual Climate Actions Progress Reports*, etc. Also, such need has been inked at the 12th FYP which can be considered the highest political guidance of China's development. Firstly, the *Central Communist Party's Suggestion to the 12th FYP* (2011-2015) published in October 2010 has clearly suggested to implement environmental taxation system and establish progressively an emission trading system to reduce the CO_2 emissions in China. Thereafter, the final version of the 12th FYP published in March 2011 which has put the environmental protection a priority has confirmed such willingness of using more economic instruments for addressing climate change as well as other environmental and resource problems. In an attentive to raise the share and contribution of market-based instruments together with well designed command and control policies, the climate change and energy saving problems could probably be addressed with a lower cost.

International challenges of China's carbon pricing policies

We have demonstrated why there is a domestic need of implementing market-based instrument in China for addressing climate change. As have been mentioned in introduction, the need of strengthening the efforts for addressing the climate change is both at domestic and international levels for China. However, among blockages of international cooperation which aims to consolidate global mitigation efforts, recent debates on carbon leakage, competitiveness and related remedying measures such as border carbon measures (BCM) have generated negative impacts which lower the pace of global climate efforts. Herein lays the challenge of implementing carbon pricing policies in China, which could contribute to lessening the carbon leakage and strengthening global climate efforts. The following sections in this part focus on the carbon leakage and competitiveness issue, the insufficiency of current Chinese policies in terms of reducing carbon leakage and potential contribution of carbon pricing policies.

5. Carbon leakage and competitiveness and the consequence to global emission reduction efforts

5.1 Theoretical forms of carbon leakage and competitiveness problems

The "common but differentiated responsibility" under the Kyoto Protocol ensures that Annex I countries should implement more stringent climate policies while non-Annex I countries should introduce properly climate policies. This creates different carbon prices among countries using different policies. Theoretically, if the domestic industries of a country (for example Europe) are exposed to higher carbon cost than the industries in foreign countries which have lower carbon cost (for example, China here), other things being equal, this will engender two parallel effects that reduce the effectiveness of domestic climate policy. First, it could weaken the competitiveness of domestic industries which would encounter a reduction of their profit margin and/or market share (at domestic and/or international market) vis-a-vis foreign industries having lower carbon cost. Second, it would generate increasing imports from and/or industry relocation to regions with lower carbon cost. This would engender GHG emissions increase (known as carbon leakage) which reduces the level of net global GHG emissions decrease that the domestic climate policy would have engendered. Suppose that domestic industries have relatively lower carbon intensity than foreign industries, table one enlists possible theoretical competitiveness loss and carbon leakage forms for a country which unilaterally implements high carbon cost at domestic.

Two major forms of measures could be used to reduce carbon leakage and/or protect domestic industry's competitiveness but the use of each single measure submits to different drawbacks. First, to reduce the stringency of domestic climate policy could lower the domestic industries' carbon cost but it could also reduce the effectiveness of domestic climate policy efficiency. Second, border carbon measures which charge a similar carbon price to domestic level on imports from countries where the carbon price is not comparable to domestic level could ensure the domestic climate policy effectiveness. However, it could also divert international trade flow which increases the exchange among third countries and generate incremental emissions due to such exchange increase. Further, such measure could generate trade war. Table two summarizes.

Table 1. Theoretical impacts of higher domestic carbon cost

Impact to investment	Competitiveness	Carbon leakage
1. Shut down domestic installation and relocate to foreign countries	GDP and employment loss at domestic;	Emissions due to export from foreign country to domestic country minus emissions at domestic before relocation.
2. Shut down domestic installation	Idem	No leakage effect due to the shutdown; but may have leakage if imports of domestic increase after the shutdown
3. Keep current production and make no further investment	Market share or profit margin losses due to higher carbon cost at domestic and foreign market.	The increase of emissions from exports of foreign countries to domestic country plus the reduction of emissions of domestic product due to higher carbon cost
4. Keep current production and make further investment in foreign countries	Idem to 3 + loss of domestic investment and FDI in the future	Leakage due to current production is identical to 3. Leakage due to future investment in the foreign country is same to 1.

Source: author

Table 2. Forms and drawbacks of measures lessening carbon leakage and competitiveness problems

Action	Forms	Major drawbacks
Reduce domestic policy stringency and no border measure	Free quotas under ETS; Lower tax rates under CT	Reduce domestic climate policy efficiency; Less incentive and stimulation to green sectors development (long term green sector competitiveness disadvantage)
	Export carbon cost refund for domestic exports	No impact on foreign imports in domestic country; Difficult to refund export carbon cost under ETS
Maintain/increase domestic policy stringency with border measures	Import carbon tariffs or imports should buy domestic ETS quotas	Could not limit and could increase trade among other countries; Uncertainty of WTO compatibility; Risks of trade war
	Export carbon taxes in foreign countries	Could not limit and could increase trade among other countries; Could not reduce the competitiveness and carbon leakage problem generated by the loss of domestic country's products in foreign countries' domestic market.

Source: author

5.2 Real impact: dilemma facing carbon leakage and competitiveness loss

Despite the theoretical relevance of the existence of carbon leakage and competitiveness and the effectiveness of related coping measures, **literature so far finds mixed results on the significance of carbon leakage** (Elliott et al., 2010; Babiker and Rutherford, 2005) and **questions the effectiveness of BCM both in terms of CO2 emissions reduction** (Böhringer et al., 2010; Houser et al., 2008) and **international diplomatic strategies**[15]. In fact, according to major ex ante studies, only a few sectors and/or products (such as cement, steel and aluminum) which are very carbon-intensive could be under significant competitiveness and carbon leakage impact under EU ETS (Demailly and Quirion, 2008; Ponssard and Walker, 2008; Hourcade et al., 2007; Mathiesen and Maestad, 2004). However, carbon leakage and competitiveness have been served as an eloquent political argument or lobby that have constituted (at least partially) a blockage for the implementation of stricter and more effective climate policies in Annex I countries. Apparently, integrating the competitiveness and leakage concerns into the climate bill seems to be an indispensable safeguard for ensuring the implementation of climate policies in regions such as Europe and the United States.

[15] See "EU attacks carbon border tax initiative", FT Oct. 14, 2009, http://www.ft.com/cms/s/0/7cba7a90-b8e3-11de-98ee-00144feab49a.html#axzz1LBSjPzro.

However, the climate policies implementation of such countries, particularly of Europe which is considered as a leader of climate actions in the world, seems to face **a dilemma**[16]: if Europe aims to lessen the short-term damage due to carbon leakage and/or competitiveness and makes free allowances of quotas in EU ETS, this could slow down the development of green sectors and make Europe a disadvantage position comparing to countries which support importantly the development of green economy[17]. If Europe adopts full auctioning of CO2 quotas and introduces border carbon measures both to protect domestic industry competitiveness and to create incentive for (enforcing) other countries to implement more stringent climate policies, this could ensure the efficiency of the development of green economy and CO2 emissions reduction. However, not to mention its WTO-compatibility, border carbon measures, instead of leveling the carbon playing field, risks generating potential trade wars and also provoking fairness debate under the common but differentiated responsibility logic and would by consequence drags back the global efforts of mitigating GHG emissions.

5.3 China in the literature of carbon leakage and China's reaction

The discourse of carbon leakage, competitiveness as well as BCM has triggered furious debates among developing countries. Not surprisingly, China is the most targeted country in the literature of carbon leakage and competitiveness given its high export market shares and large domestic capacity of producing energy-intensive products. For example, Gros (2009) has favored the use of import carbon tax in Europe particularly on China given the lack of carbon price on Chinese manufacturing sectors. Lord Turner of the *UK Committee of Climate Change* has proclaimed that "the government should 'rigorously assess' bringing in levies on cheap imports from countries outside the European Union, which are not subject to carbon-related costs such as the EU emissions trading scheme"[18]. Carbon leakage, competitiveness and particularly the use of BCM in developed countries have triggered criticism from the main target country, namely China. Wielding the threat of a trade war, Chinese officials have reasserted their rejection of any climate measures on Annex I country borders on the grounds that these would be disguised protectionism, both **inefficient and unfair**[19].

In a world of unequal carbon prices, the economic rationale for a carbon tariff seems straightforward (Krugman, 2009). In a global view, the effectiveness of domestic

[16] The imperfection of different tradable quota allocation methods to address the leakage concern has been well discussed by Heilmayr and Bradbury (2011).

[17] Although for the third phase of EU ETS the electricity sectors submit to full quota auctioning, most of industrial sectors receive free allowances or 80% free allowance at the beginning of the period. The large share of free allowances could still lower down the path of green innovation comparing to full auctioning.

[18] See "Trade row looms as adviser calls for carbon tax on China", Guardian 1 March 2010, http://www.guardian.co.uk/business/2010/mar/01/carbon-tax-trade-china

[19] Read for instance "China: carbon tariff could trigger trade war", People's Daily Online, July 03, 2009 http://english.peopledaily.com.cn/90001/90778/90857/90861/6693060.html; "China says 'Carbon tariffs' proposals breach WTO rules", Reuters, Beijing 3 July, 2009. http://www.reuters.com/article/idUSTRE5620FV20090703?pageNumber=1

emission reduction efforts could be dampened by increasing imports from countries where the emission reduction efforts are less stringent. However, three arguments have been put forward in the case of the European Union Emission Trading Scheme (EU-ETS) questioning each the efficiency of BCM. First, literature revealing the insignificance of carbon leakage has frequently been cited as proof of the uselessness and even fallacy of border measures (Wang and Chen, 2010). In addition, the issue of measuring leakage itself raises controversy, with some estimates provided by Western academics deemed subjective and partial by their Chinese counterparts (Wang, 2010). Second, even if full auctioning were used inside the EU to allocate allowances within member countries, leakage avoided by BCM could be limited in scope and even nil, because of trade diversion across non Annex 1 countries. Given that the major demand increase for energy-intensive products comes from developing countries, limiting their imports into the EU market could divert trade among developing countries, and sometimes create it, thereby increasing overall CO2 emissions worldwide (Houser et al., 2008). Finally, political economy considerations around implementation issues also raise inefficiency concerns. The risk perceived from a Chinese perspective is that BCM may be all the more easily manipulated by vested interests making GHG emissions from imported products difficult to estimate, monitor and control[20].

The Chinese Premier, Wen Jiabao, has long asserted that the principle of "common but differentiated responsibilities" (CDR) is the core and bedrock of international cooperation on climate change and must never be compromised[21]. In substance, the UNFCCC and Kyoto set the stage for a world of unequal carbon prices: by virtue of CDR and the scope of the Kyoto Protocol, no unique carbon price could emerge from the Convention, and therefore leakage is unavoidable. **Author's interview** vis-a-vis Chinese officials of Ministry of Finance and Ministry of Commerce has provided further confirmation of such stance: **using a BCM to set the same carbon price for European ETS products and Chinese imported products, for instance, violates the unequal price implicit rule and breaches the fairness principle enshrined in the Convention**.

Second, despite the fact that China aims to change its major economic growth driver from export into consumption, export remains still an important contributor to economic prosperity. China's accession to the WTO was, to a large extent motivated by the possibility of securing export gains and hence GDP increase by accessing foreign markets at most-favoured-nation tariff levels. Moreover, the current WTO negotiation round – the Doha *Development* Agenda – confers particular market access rights, or at least expectations, on China as a developing country member. Author's discussion with officials from Ministry of Commerce has also shown that the **implementation of a BCM in its export markets would infringe China's development**

[20] See Ministry of Commerce of China: protectionism behind border tariffs proposal, ChinaNews, July 15, 2009, http://finance.people.com.cn/GB/9661381.html (in Chinese)

[21] "Common but differentiated responsibilities' must never be compromised: Premier" China.org.cn, 18 December, 2009. http://www.china.org.cn/environment/Copenhagen/2009-12/18/content_19094598.htm

rights, and is thus considered unfair (author's interview with anonymous officials of Ministry of Finance and Ministry of Commerce of China).

Without dismissing the economic and commercial issues at stake under cover of national initiatives to curb global warming, China's rejection of BCM and recent policy shift towards internalising GHG emissions cost can be understood as one single claim to have its new responsibility and pro-activity on climate affairs recognised for their own value. **A convincing explanation of China's original trade-and-climate stance may lie not in economics, but rather in politics.** Methodological difficulties comparing mitigation efforts across countries (Grubb and Ward, 2009; Ma et al., 2009) leave room for subjective political judgment of the value of these and for the possible pre-emption of defaulting by any one country (cf. Para. 15-16 of 7128/09, Council Conclusion of the EU). From a Chinese political perspective, **CBM options contemplated by Annex I countries unilaterally convey the signal of a China that is perpetually falling short of international standards and of sharply increasing responsibilities** (Wang and Chen, 2010).

6. Insufficiency of current Chinese policies for addressing carbon leakage and competitiveness problems

It is no doubt that there is a strong domestic willingness of curbing the growth of energy-intensive sectors and the fact that current Chinese policies and possible policies to be implemented in the short future can contribute to the LCE development in China. However, Chinese policies remain so far inconvincible for lessening effectively carbon leakage/competitiveness problems (at least for certain Annex I countries). This falls short in clearing the blockage effect due to the presence of carbon leakage and competitiveness in EU and US and strengthening mitigation actions in such countries, despite the fact that the existence of carbon leakage has not yet reached to a consensus. This section therefore demonstrates such insufficiency of major domestic policies in China.

6.1 Possible domestic carbon pricing policies in the short term

The first-best option to address the carbon leakage and competitiveness as well as to strengthen the global efforts of reducing CO2 emissions is to level up the domestic carbon prices. As has been shown previously, it can be expected that China would implement more efficient policy packages in order to fulfill the LCE needs and achieve its national pledges of UNFCCC by 2020[22]. Carbon pricing policies will be a challenging but indispensable component given its comprehensiveness, transparence and facility for international coordination, among policy options. However, the starting carbon price would probably be low and could not effectively lessen the carbon leakage and competitiveness problems, at least theoretically.

[22] China will endeavor to lower its carbon dioxide emissions per unit of GDP by 40-45% by 2020 compared to the 2005 level, increase the share of non-fossil fuels in primary energy consumption to around 15% by 2020 and increase forest coverage by 40 million hectares and forest stock volume by 1.3 billion cubic meters by 2020 from the 2005 levels.

Certainly, the merits of implementing domestic carbon pricing policy in China are numerous. For example, it sends a clear price and political signal to domestic industries on the progressively increasing carbon cost. It can also gain China sufficient international acknowledgements for addressing climate change and facilitate further implementations of more stringent carbon pricing policies. Of course, it could also exempt China from any border tax measures attempted in EU or US within the WTO framework. However, if implemented at a low price, such policy will always put the allegation of leakage and competitiveness in vain. A low carbon price in China provides even a clearer theoretical base for carbon leakage and competitiveness loss due to unequal carbon prices in the world, thus deleting no blockage for implementing more stringent climate policies in the EU and US, a result contrary to strengthening the global mitigation actions.

6.2 Export restrictive policies on energy-intensive sectors

The tax of direct emissions for imported products in Annex I countries should not occur once such emissions have already been taxed at export gates by the exporting country (Liski and Tahvonen, 2002). However, **the current export VAT rebate and export tax policies in China fall short on unique, explicit and predictable carbon prices** although they have been pronounced as climate policies officially (Wang and Voituriez, 2010). Therefore, such policies are more likely to be a measure for coping with domestic environment and resource problems engendered by the export than genuine climate policies.

6.3 Domestic command-and-control policies

The limitation of the expansion of (demoded) energy-intensive capacities could, in a certain degree, limit the industry relocation to China and thus allege the leakage concern in Annex I countries. However, it has several drawbacks that fail to effectively lessen the leakage effect. First, it does not limit the investment of new capacities with advanced technology in energy-intensive sectors. Therefore, the reduction of leakage from industrial relocation is only partial. Second, it could not reduce the leakages engendered from increasing Chinese export to Annex I regions.

However, there are also some command-and-control policies which can (theoretically) contribute to lessening the carbon leakage problems. For example, China has been reducing the overcapacity of energy-intensive sectors, resorting to measures such as the closure of outdated and inefficient installations domestically (steel, cement and coke, notably) for the last couples of years. Similarly, the *Catalogue for the Guidance of Foreign Investment Industries*, published annually by the Chinese government, has classified foreign investment in energy-intensive sectors as either “unfavourable” or “prohibited”, depending on the sector, since 2007. As China continues to tighten market access criteria for energy-intensive sectors, these policies could be deemed capable of reducing the risk of carbon leakage through industry relocation and dismissing partially the “pollution haven” argument levelled against China. Yet, relative to economic instruments, such policies usually fall short on comprehensiveness and transparency and have so far gained limited recognition by China's trade partners (Zhang, Z.X., 2010).

Subject and organization of the thesis

7. Chapter conclusion, subject and organization of the thesis

This chapter demonstrates both domestic and international contexts that the implementation of the carbon pricing policies in China would face. First, it shows that current domestic low carbon policies are principally composed by command and control policies of which the lack of cost-effectiveness has been well noticed by the central government. This is the key reason of the **increasing domestic need** of implementing carbon pricing policies in order to develop more cost-effectively a low carbon economy. Second, it shows that although the carbon leakage and competitiveness problems have received so far mixed research results, they constitute a **blockage** for countries like European Union to implement more stringent climate policies. Moreover, they could **dampen the confidence building** among countries and lower the efforts of strengthening of global efforts for addressing climate change. It also shows that China is the major target discussed in the carbon leakage literature and the current Chinese policies fall short on lessening the carbon leakage problems, although some other countries can also be considered "responsible". In this term, they could not generate a positive effect contributing to strengthening global climate efforts.

In such contexts, the thesis studies whether there is a case for China to implement a win-win carbon pricing policy which provides a pro-active strategy both for developing cost-effectively domestic low carbon economy and addressing the competitiveness and carbon leakage problems, thus contributing to consolidating global mitigation efforts. It examines the rationale, impact and feasibility of **domestic and export differentiated carbon pricing policies** package (shortly for DEDCP). Such a package is composed by two parts: First, it ensures implementing domestic low carbon price in the case of the difficulty of introducing high domestic carbon price in the short term. Second, it proposes to introduce high carbon price into China's export as a **transitional measure** until domestic carbon price reaches to a comparable level.

The thesis is composed by three parts and is organized as follows:

<u>Part One</u> presents the theoretical fundamentals, the methodology, data and its adjustment. It is composed by two chapters:

Chapter One presents theoretical fundamentals and methodology. Both quantitative and qualitative approaches are used in the thesis where the general equilibrium theory constitutes an important share of analysis which deserves a detailed instruction. It first constructs a two countries, two goods and one pollutant simple **theoretic model** which demonstrates the efficiency of domestic carbon pricing policy, the problem of carbon leakage and competitiveness under unequal carbon prices and the rationale of using border carbon measures (import or export carbon prices) in developed or developing countries. It then presents the dynamic national CGE model, namely **SIC-GE model** of State Information Center (SIC) of China which is used as a major policy simulation tool in the thesis and demonstrates in a detailed manner energy-climate and trade modules. The SIC-GE model is co-developed by SIC and Monash University of Australia and serves as a **key simulation tool for** policy making of **Chinese central government**.

Chapter Two presents data and makes own adjustment to ensure accuracy. The thesis prioritizes Chinese data once available and uses IPCC and other sources when related data is missing in China. It first demonstrates the statistical improvements and drawbacks of Chinese statistical data with a comparison to international/OECD standards. This contributes to understanding the **degree of representativeness** of results obtained based on **Chinese data**. It then explains the most detailed Chinese data of sectoral energy consumption (by fossil fuels types) which does not separate intermediate and end-use consumptions and makes **own adjustment** in order **to prevent double counting problems**. Such data adjustment is so far not explicitly demonstrated by existing studies and could therefore be used by further studies. It finally presents other related data used by the thesis.

<u>**Part Two**</u> analyses the currently proposed domestic carbon pricing policies. It is composed by two chapters:

Chapter Three uses **two quantitative approaches** to assess the economic and climate **impacts of domestic carbon price** of which a short-term implementation has been announced officially. By firstly using a linear system similar to the EU Commission’s approach of determining carbon leakage impacts, it provides a first-step, first-view result on the short-term competitiveness impact once a carbon price is introduced in China, which is of particular importance for policy makers. It then uses the SIC-GE model to simulate short- and long-term impacts of carbon price with different electricity price pass-through and revenue redistribution scenarios in order to provide a complete policy making basis.

Chapter Four underlines **uncertainties and barriers** of the short-term implementation of domestic carbon pricing policies in China although such an implementation has been officially announced. First, it shows an example of the difficulty that fuel tax reform suffered in China during the last two decades and highlights the potential legislative and institutional barriers that the implementation of a carbon price could encounter. Second, it examines the compatibility of carbon tax and emission trading in China by highlighting different and potentially conflicting institutional interests. Third, it discusses possible options of introducing a carbon price (directly as a new policy or indirectly as integration of carbon price into existing domestic price policies, such as consumption tax, resource tax, etc.). It finally provides recommendations for accelerating the implementation and guaranteeing a good function of carbon pricing policies in China.

Part Three examines the existing export pricing policies and discusses the feasibility of short-term introduction of a comprehensive and comparable export carbon price. It is composed by three chapters:

Chapter Five first reviews the incentives of using export tax measures in the world. It then focuses on the **incentives** of the massive implementation of export VAT refund rebate and export tax (EVRRET) policies on energy-intensive products **in China** since 2007. First, it shows that **the export of energy-intensive goods is not wished by the Chinese government** as a driver of GDP and export growth. Second, by reviewing official documents and making own interviews with senior officials, it confirms that **the major objective of using EVRRET is for environment and energy saving ends**, although EVRRET are temporary and varies both on tax rates and taxed products. It finally makes calculation on the **implicit carbon price** that EVRRET generate both at product and sectoral level where related data is available. It finds that, except cement, EVRRET generate a comparable and even higher carbon price than EU ETS price.

Chapter Six aims to provide a comprehensive export carbon pricing policy in China. It proposes to **fix the rates of export non-refundable VAT** (equal to domestic VAT minus export VAT refund rate) **which are equivalent to a certain carbon price** (20$/tCO2 for example). It shows that the introduction of 20$/tCO2 would not generate additional cost on most of the energy-intensive sectors given that their current export non-refundable VAT rates are higher than the equivalent rate that 20$/tCO2 would entail. This chapter proposes to fixe these equivalent rates and to **announce their unique use for climate change**. The export non-refundable VAT of a certain product could still increase and vary beyond this fixed equivalent rate but should be announced for non-climate ends.

Chapter Seven provides an **alternative option** of introducing comprehensive carbon price on China's export. It analyses the feasibility of introducing an **export carbon tax** by using SIC-GE model. It shows that the introduction of an export carbon tax would generate **very little GDP impact** but entail **significant export structure change**: the export of most energy-intensive products would decrease while the export of certain products with higher value-added would increase. Such scenario **corresponds to China's policy orientation** of restructuring its export. Further, this chapter discusses the **WTO-compatibility** of export tax of China. It shows that so far the current export tax on energy-intensive sectors do not raise WTO dispute and could be both favorable for China and major Annex I countries in terms of climate change. It finally proposes to make **China-EU alliance on the use of export carbon tax** in China as a transitional measure before that China introduces domestic comparable carbon prices.

References:

Ang, B.W. and S.Y. Lee, 1994. Decomposition of industrial energy consumption – some methodological and application issues, *Energy Economics* 16, pp.83-92.

Ang, B.W. and F. Q. Zhang, 2000. A survey of index decomposition analysis in energy and environmental analysis. *Energy* 25, 1149-1176.

Ang. B.W., 2004. Decomposition analysis for policymaking in energy: which is the preferred method? *Energy Policy* 32: 1131-1139.

Ang. B.W., 2005. The LMDI approach to decomposition analysis: a practical guide. *Energy Policy* 33, 867-871.

Babiker, M.H., Rutherford, T.F., 2005. The economic effects of border measures in sub-global climate agreements, *Energy Journal* 26(4), pp.99-126.

Böhringer, C., Fischer, C., Rosendahl, K.E., 2010. The global effects of sub-global climate policies, *The B.E. Journal of Economic Analysis & Policy* 10(2), Symposium, Article 13.

Chai, J., Guo J., Wang, S. and K.K. Lai, 2009. Why does energy intensity fluctuate in China? *Energy Policy* 37, pp.5717-5731.

De Boer, Y., 2007. Changements climatiques 2007 : une année décisive, *Liaison Energie Francophonie* 75, pp. 86-90.

Demailly, D., Quirion, P., 2008. European emission trading scheme and competitiveness: a case study on the iron and steel industry, *Energy Economics* 30, pp. 2009-2027.

Dong, W., Meng, X., Duan, H., Deng, X., 2011. Low carbon development in energy sector: review, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.59-113. (in Chinese)

Droege, S., 2011. Using border measures to address carbon flows, *Climate Policy*, 11(5), pp.1191-1202.

EIA, 2009. 2009 International Energy Outlook, US Energy Information Administration (EIA).

Elliott, J., Foster, I., Kortum, S., Munson, T., Pérez Cervantes F., Weisbach, D., 2010. Trade and carbon taxes, *American Economic Review* 100(2), pp.465-469.

Gros, D., 2009. A border tax to protect the global environment?, *Center for European Policy Studies Working Paper*, Brussels.

Grubb, M., Ward, M., 2009. Comparability of efforts by Annex I countries: an overview of issues, *Climate Strategies Report*, Climate Strategies, Cambridge.

He, J., Deng, J., Su, M., 2010. CO_2 emission from China's energy sector and strategy for its control, *Energy* 2010, pp. 4494-4498.

Heilmayr, R., Bradbury, J.A., 2011. Effective, efficient or equitable: using allowance allocations to mitigate emissions leakage, *Climate Policy*, 11(4), pp.1113-1130.

Hourcade, J.-C., Demailly, D., Neuhoff, K., Sato, M., 2007. Differentiation and dynamics of EU ETS industrial competitiveness impacts, *Climate Strategies Report*, Climate Strategies, Cambridge

Houser, T., Bradley, R., Staley, B.C., Werksman, J., Heilmayr, R., 2008. *Leveling the Carbon Playing Field: International Competition and US Climate Policy Design*, Peterson Institute for International Economics, Washington D.C.

IPCC, 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Pachauri, R.K. and Reisinger, A. (Eds.), IPCC, Geneva.

Jotzo, F., 2011. Comparing the Copenhagen emissions targets, *Crawford School Centre for Climate*

Economics & Policy Paper No. 1.10, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1878905

Krugman, P., 2009. Climate, Trade, Obama, *New York Times*, 29 June, 2009. http://krugman.blogs.nytimes.com/2009/06/29/climate-trade-obama/

Li, H., 2011. Indicators of low carbon development in China, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.355-372. (in Chinese)

Liao, H. and Y.M. Wei, 2010. China's energy consumption: A perspective from Divisia aggregation approach, *Energy* 35, pp.28-34.

Ma, L., 2011. Market structure reorientation and development quality, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.20-28. (in Chinese)

Ma, L., Li, H., 2011. Responsibility of energy saving targets, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.29-37. (in Chinese)

Ma, X., Li, J. and Zhang, Y., 2009. An ineligible question before Copenhagen, the BAU scenario under international negotiation and climate change researches, *International Economic Review* 6 (2009), 5-8. (in Chinese)

Mao, R.B., Chen, Q.T., 2008. A Study of Approaches and Methods to Meet China's 20% Energy Efficiency Target for 2010, Science Press, Beijing, 2008. (in Chinese)

Mathiesen, L., Maestad, O., 2004. Climate policy and the steel industry: achieving global emissions reductions by an incomplete climate agreement, *Energy Journal*, 25(4), pp. 91-114.

McKibbin, W.J., Wilcoxen, P.J., 2002. The role of economics in climate change policy, *Journal of Economic Perspectives* 16 (2), pp. 107-129.

National Development and Reform Commission of China (NDRC), 2007. *China's National Climate Change Programme*, available at http://www.ccchina.gov.cn/WebSite/CCChina/UpFile/File188.pdf

Pan, J., Zheng, Y., Zhang, A., 2009. Preliminary studies on the impact of low carbon development on employment in China, http://www.china.com.cn/international/txt/2009-12/11/content_19050870.htm (In Chinese)

Ponssard, J.-P., Walker, N., 2008. EU emissions trading and the cement sector: a spatial competition analysis, *Climate Policy*, 8(5), pp. 467-493.

Rogelj, J., Nabel, J., Chen, C., Hare, W., Markmann, K., Meinshausen, M., Schaeffer, M., Macey, K., Höhne, N., 2010. Copenhagen Accord pledges are paltry, *Nature* 464, pp.1126-1128 (22 April, 2010)

State Council Information Office, 2008. *White Paper: China's Policies and Actions on Climate Change*, Beijing.

Stern, N., 2007. *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge.

Transparency International, 2011. Ensuring corporate transparency to mitigate climate change, *Policy Position* 2011/02, available at http://www.transparency.ch/de/PDF_files/Newsletter/2011_TI-S_Policy_Position_Climate_change.pdf

Tubiana, L., Wang, X., 2011. La croissance verte, une option pour la Chine?, La Chine au milieu du monde, *AGIR* 46, pp.149-162.

Wang, A., 2010. Could policymaking be based on the conclusion ignoring the related rules and inconsistent with the facts?, available at http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2546.pdf.

Wang, X., Chen, Y, 2010. Disentangling border carbon tax – an analysis of the EU policy, *Chinese Journal of European Studies*, 166, pp.44-48. (in Chinese)

Wang, X., Voituriez, T., 2010. China's export tax and export VAT refund rebate on energy-intensive goods and their consequence for climate change. In Soares, C.D., Milne, J.E., Ashiabor, H., Kreiser, L., and Deketelaere, K. Eds., *Critical issues in environmental taxation, International and comparative perspectives,* Vol. VIII, Oxford University Press, New York, pp.408-428.

Ye, R., von Weizsacker, E.U., 2009. Economic instrument for energy efficiency and the environment, *China Council for International Cooperation on Environment and Development (CCICED) Policy Research Report*, Beijing, 2009.

Yu, Y., Ma, L., Song, W., 2011. Low carbon development in manufacturing sector: review, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.114-164. (in Chinese)

Zhang, Y., 2010. Supply-side structural effect on carbon emissions in China, *Energy Economics* 32, pp.186-193.

Zhang, Z.X., 2010. The US proposed carbon tariffs and China's responses, *Energy Policy* 38, pp.2168-2170.

Zhao, X., Ma, C., Hong, D., 2010. Why did China's energy intensity increase during 1998-2006 : decomposition and policy analysis, *Energy Policy* 38, pp.1379-1388.

Zhou, S. (Minister of the Environmental Protection of China), 2008. Preface, In: Zhang, K., Pan, J., Cui, D., Eds., *Introduction to low carbon economy*, China Environmental Science Press, Beijing. (in Chinese)

Chapter One. Theoretical fundamentals and Methodology

1. Introduction

This chapter presents the methods used for making an economic and political analysis on domestic and export border carbon pricing policies in China. The thesis contains a double-objective: first, to provide a scientific-based and complete analysis both for policy making on carbon pricing in China and to contribute to better understanding Chinese policy for other countries; second, to give practicable policy recommendations for both domestic and export carbon pricing policies which could lead to a win-win solution both for China and the world in terms of low carbon development. Therefore, both qualitative and quantitative approaches are used as complementary methods in order to obtain this double-objective. **Qualitative analysis** is used to clearly demonstrate the Chinese contexts and analyze potential obstacles of policy implementation. In particular, author's interviews and discussions with anonymous senior officials of major ministries[23] of China play an important role both for confirming the key finds and for ameliorating policy recommendations of the thesis. **Quantitative analyses** are composed by linear model and CGE model assessments. The former is used principally to calculate key parameters of carbon pricing policies, for example the carbon price level, the implicit carbon price, etc. The latter is based on the linear approach and provides policy simulations.

Noticeably, the general equilibrium theory and the CGE approach occupy an important policy space in key analyses of climate change and energy issues in China. For example, the CCICED (China Council for International Cooperation on Environment and Development) 2009 annual report on economic instruments for energy efficiency and environmental protection has adopted a CGE model to analyze the impact of carbon tax on Chinese economy (Ye and Weizsacker, 2009). Liang et al. (2007) have also adopted a CGE approach and examined the impact of carbon tax, with a particular focus on five major energy-intensive sectors. Wang et al. (2009) and Wang (2003) have also adopted CGE analyses on climate policies. Besides, technology models and/or hybrid models have also focused on the CO2 emissions of China. For example, Jiang et al. (2009) by using IPAC-AIM model calculated the total and sectoral CO2 emissions of China by 2050. Dai et al. (2011) examined China's climate commitment by using AIM/CGE model. However, CGE module always constitutes a kernel part in such models.

This provides a solid argument for the choice of the thesis by using **SIC-GE model** of **State Information Center of China** (SIC) which is co-developed by Monash University of Australia and SIC. So far, this model serves as an auxiliary tool for public policy decision making of Chinese central government. It has conducted several policy

[23] These ministries include, National Development and Reform Commission (NDRC), Ministry of Finance (MOF), Ministry of Environmental Protection (MEP) and Ministry of Commerce (MOFCOM).

simulation tasks such as the impact of energy pricing, the border tax adjustments as well as non energy issues for example the impact of Yuan appreciation. Therefore, the use of SIC-GE model confirms at least two things: first, it ensures the credibility of scientific analysis; second, key results obtained by the model can be presented at the central government of China.

In order to provide a comprehensive understanding of the interaction between domestic and border carbon pricing policies and to ensure the clarity of results obtained by SIC-GE model, this chapter is organized as follows: Part Two makes a brief review of general equilibrium theory; Part Three constructs a very simple two countries, two goods, one global pollutant model in order to demonstrate some theoretical fundamentals of domestic and border carbon pricing policies; Part Four makes a transition from general equilibrium theory to CGE assessment by summarizing some key issues of CGE analysis with a comparison with the classical general equilibrium theory; Part Five presents the SIC-GE model and shows in details the energy-climate and export modules of SIC-GE model before concluding.

2. Review of general equilibrium theory

Among other founders of marginalism, Léon Walras' contribution could be considered outstanding (Lallement, 2000). If the formidable work of Menger and Jevons opens the door of the relation between utility and price by demonstrating the price determination by consumer demand, the findings of Walras (particularly in *Eléments d'économie politique pure*) depict explicitly the whole general economic system where the equilibrium can be achieved by what Walras called "tatonnement"[24]. The first half of the twentieth century, particularly the period between two World Wars, constitutes a transition phase of general equilibrium theory development (Zylberberg, 2000). In general, the period between 1920 and 1940 has been marked by a general equilibrium theory research under the impact of Walras. However, the development of economic theory during this period has been dominated by a trend of, first, the partial equilibrium theory developed by Marshall and Pigou; second, the Keynesian revolution and finally, the econometrics under macroeconomic theories. Despite the fact that general equilibrium theory has been treated by eminent economists by that time (for example, Schumpeter, Moore and Schultz, etc.), the real step forward of general equilibrium theory could be considered done by Hicks (1939), Allais (1943), Samuelson (1947), Arrow and Debreu (1954) from the beginning of the fortieth of last century. The question of the existence of general equilibrium which has been already treated before but has not been solved yet at the time, has lead to a success of mathematical application to the economic analysis of general equilibrium. Particularly, Gérard Debreu is considered a

[24] One of the innovative spirits that Walras has given heritage to the following researches on economics is the demonstration. According to Walras himself, "*On compte aujourd'hui je ne sais combien d'école historique, … Pour moi je n'en reconnais que deux: l'école de ceux qui ne démontrent pas et l'école que j'aspire à voir se fonder, de ceux qui démontrent leurs énociations*" (Eléments p.699). Together with Vilfredo Pareto who integrated the consideration over individual and collective welfare into the GE theory, the GE theory under the name of Walras and Pareto is categorized Lausanne School.

major contributor synthesizing such mathematical applications. The famous work of *Theory of Value* published by Debreu in 1959 has not only provided a good reference of general equilibrium theory, but also of the general neo-classical theory (Hahn, 1984). Here, the basic framework which can be observed from the nowadays CGE approach has been formulated by Debreu: all description of economic phenomenon must contain the basis of agent – preference, initial donations, available technologies, etc. – and a maximization principle (utility, profits, etc.) subject to resource and technology availabilities.

However, the program of general equilibrium treated by Walras, Hicks, Samuelsson, Arrow and Debreu has also encountered difficulties and limits on its robustness, due to the Sonnenschein-Mantel-Debreu theorem (Kirman, 1989). The problem of the multitude of agents remained a major vacuum given that the successive development of general equilibrium model usually defines a limited (restrained) number of representative agents. Also, the perfect/complete market assumption of general equilibrium theory limits the application of general equilibrium to the real world, although general equilibrium has a strong descriptive role of the real world economy. So far, modern studies on the general equilibrium with incomplete market (information) still continue. Despite the fact that the general equilibrium theory still encounters difficulties, it constitutes one of the prevailing theories of mainstream economics and provides an important basis for CGE analysis. Appendix A, B and C therefore provides, respectively, a simple general equilibrium model framework as well as that of two fundamental general equilibrium models, namely Hechscher-Ohlin and Armington Model in order to provide a solid basis for understanding general equilibrium theory and the solution of equilibrium.

3. A simple model: domestic and border carbon pricing policies

3.1 Hypothesis and the model

There exist a number of studies on the theoretical linkage between trade and environment and related policies (for example, Copeland and Taylor, 2009; 2005; 2004). We develop a general equilibrium theoretical model in this section in order to **demonstrate the impact of domestic and border carbon pricing policies** in a world composed by two countries (developed and developing countries), two goods and one pollutant as CO2 emissions. We adopted the same model developed by Copeland and Taylor (2003) and merely expand the pollution which has only local impact in the original model to global pollutant. In order to present coherently key issues related to the subject of the thesis, some secondary contents of the whole model construction are not included here but can be found at Copeland and Taylor (2003). However, they do not necessarily dampen the comprehensibility of kernel results of the new model here.

3.1.1 Production function

Assume that in a small country, there are two goods X and Y and the production of these goods uses two factors capital (K) and labor (L) which are inelastic to demand.

The production of X is pollutant and capital-intensive and the production of Y generates no pollution and is labor-intensive. The two goods are exchanged in the world market and their prices are fixed due to small country assumption. The pollution (Z) is generated by the production of X and it only has an impact on consumer welfare and does not affect the production of X and Y.

Assume that the two goods are produced under CES technology. For the production of X, each firm assigns an endogenous part θ in order for depollution. The higher the level of θ the lower the emission level but the higher amount of X required for emission abatement. The production function of X and the level of Z can be given by

$$x = (1-\theta) F(K_X, L_X) \quad (1)$$

$$z = \psi(\theta) F(K_X, L_X) \quad (2)$$

Where F is increasing, concave and linearly homogenous, $0 \le \theta \le 1$, $\psi(0) = 1$, $\psi(1) = 0$, and $d\psi / d\theta < 0$. Name $F(K_x,L_x)$ the potential output of X which is the level of the output of X where the depollution effort is zero. Assume now that the factors input intensity between the production of X and the depollution functions is the same. This indicates that if a vector (K_x,L_x) is used to produce X then θK_x and θL_x are used to abate the pollution. The net output of X is then $(1-\theta)F(K_x,L_x)$. In order to simplify the demonstration, we assume that $\psi(\theta) = (1-\theta)^{1/\alpha}$ with $0 < \alpha < 1$. Therefore, equations 1-2 can be rewritten by

$$x = z^{\alpha} \left[F(K_X, L_X) \right]^{1-\alpha} \quad (3)$$

which is true as long as $z \le F$. Such form indicates that the pollution can also be considered as an input, for example, z can be considered as emissions permits.

The production of Y is simply given by

$$y = H(K_Y, L_Y) \quad (4)$$

Where H is increasing and concave.

3.1.2 Consumer utility

Assume that the consumers are identical and the pollution is considered a pure public bad. For simplicity reasons, we assume that the preference on the good consumption is homothetic and the utility function can be separated into good consumption and environmental pollution. The homothetic property assumption ensures writing the indirect utility function as a function of real revenue (nominal revenue divided by a price index). This assumption also ensures that the relative demand is not affected by the revenue changes. Moreover, the separate indirect utility assumes that the marginal rate of substitution between X and Y is not affected by the environmental performance and it also assumes that the prices of goods do not have impact on the environmental quality demand of consumers; the pollution affects only the utility level of the agents but has no effect on their choice of the goods. The direct function of a consumer can be written by

$$U(x, y, z) = u(x, y) - d(E) \qquad (5)$$

Where E=e+e* is the global emission level which is the sum of domestic emission e and foreign emission e*. Recall that u is assumed to be increasing, concave and homothetic and d is increasing and convex, with the price, pollution and per capita revenue level considered as given, each consumer maximizes his utility. This leads to the result of indirect utility function

$$V(p, I, E) = v\left(\frac{I}{\beta(p)}\right) - D(E) \qquad (6)$$

Where p is the price of X and the price of Y is numeraire, I is the revenue and $\beta(p)$ the price index and v is the indirect utility function deduced from u and it is increasing and concave.

3.1.3 National revenue

The national revenue is endogenous in the general equilibrium framework in this appendix. It is the value of the payments of all factors including the emission abatement payment. Assume that the maximization of firm profits leads to the maximization of national revenue in a perfect competitive market. The national revenue function G is then given by

$$G(p, K, L, e) = \max_{x,y}\{px + y: (x, y) \in T(K, L, e)\} \qquad (7)$$

Where T is the production technology and is convex, double dimensional with constant return. According to the Hotelling Lemma, we have G_p=x and $G_e=\gamma$ where γ can be considered as the emission tax rate or permit price.

3.1.4 Impact of global trade

We assume that the effect of emissions is separable, that is D(E)=D(e)+D(e*) and dD(E)=D'(e)de+D'(e*)de*, the maximization problem of consumer utility is written by

$$\max_E V(p,I,E), s.c. I = G(p,K,L,e)/N \quad (8)$$

Where N is the number of agents and is assumed to be 1 here. The first-order derivative under optimum gives that

$$V_p dp + V_I dI + V_E dE = 0 \quad (9)$$

which can be rearranged into

$$V_p \frac{dp}{dE} + V_I \frac{dI}{dE} + V_E = 0 \quad (10)$$

According to our assumption of small countries, we have dp/dE=0 since the emission level does not affect the price of the good. The marginal damage of global emissions can be written into

$$\frac{dI}{dE} = MD_E = -\frac{V_E}{V_I} \quad (11)$$

Also, the revenue function I(p,e,K,L) allows writing

$$dI = xdp + \gamma de \quad (12)$$

The derivative form of equation A6 can be written

$$V_p dp + V_I dI + V_E dE = dV \quad (13)$$

Putting equation A11-A12 into equation A13, we have

$$\frac{dV}{V_I} = -\mathrm{mdp} + [\gamma - \mathrm{MD_E}(p, I, E)]\mathrm{dE} \quad (14)$$

Where x_c and x are respectively the consumption and production of X and m=(x_c-x) is the net import of X.

Proof 1

We calculate $\frac{V_p}{V_I}$. We have $v(I/\beta(p)) \Leftrightarrow v(I,p)$. With Roy's identity, for a certain level of utility given, we have $v\left(I\left(p,u\right),p\right)=u$, that is

$$\frac{V_p}{V_I}=\frac{\dfrac{\partial v\left(I\left(p,u\right),p\right)}{\partial p}}{\dfrac{\partial v\left(I\left(p,u\right),p\right)}{\partial I}}=-\frac{\partial I}{\partial p}=-x_c$$

According to equation 14, the impact of increasing global trade can be decomposed into two welfare impacts. The first part on the right side of equation 14 explains the impact of increasing global trade. For a net importer of X, the trade liberalization decreases the domestic price of X and increases the import of X, that is m>0 and dp<0, and we have –mdp>0. For a net exporter of X, the trade liberalization increases both the domestic price and export amount of X, that is m<0 and dp>0, and we still have –mdp>0. **Other things being equal, trade liberalization increases welfare level.** Such corresponds to key findings of a certain number of studies such as Bhagwati (2004) and Bhagwati et al. (1998).

The second term on the right side of equation 14 explains the environmental impact of trade liberalization. Under the presence of global pollution, the optimal climate policy based on domestic emissions in a country makes the second term a negative value if the climate policy of other countries is not optimal. Recall that we have assumed that

$$MD_E=-\frac{V_E}{V_I}=-\frac{V_e}{V_I}-\frac{V_{e^*}}{V_I}=MD_e+MD_{e^*} \qquad (15)$$

The optimal domestic policy is achieved when γ=MDe. Given that MDe*>0, we have $\gamma\text{-}MD_E<0$ and an increase of global emissions reduces the welfare effect of a country even if its domestic climate policy is optimal. The final net welfare effect would then depend on whether the trade welfare effect compensates the welfare loss due to global emissions increase.

3.2 Global trade under the presence of global pollutants

3.2.1 Introduction of a new emission function

We now introduce a new emission function in order to better examine the impact of trade liberalization under the presence of a global pollution. Assume that e*=e*(m), that is the emission of foreign country is a function of net imports of the domestic country and we have $e^*_m{}'>0$. For an exporter of X, the higher level the export (dm<0), the lower level the foreign emissions. For an importer of X, the higher level the import (dm>0), the higher level the foreign emissions. Based on equation 14-15, it can be obtained that

$$\frac{\mathrm{dV}}{\mathrm{V_I}} = -\mathrm{mdp} + [\gamma - \mathrm{MD_e}]\mathrm{de} - \mathrm{MD_{e*}}\mathrm{e^*_m}\mathrm{dm} \qquad (16)$$

Proof 2:

Given that $dD(E) = D'(e)de + D'(e^*)de^*$ and equation 15, the second term of the right side of equation 14 becomes

$$\left[\gamma - MD_E(p,I,E)\right]dE = \left[\gamma - MD_E(p,I,E)\right]d(e+e^*) = \left[\gamma - MD_e\right]de - MD_{e^*}\cdot de^*$$

With the newly introduced function, we have

$$de^* = e^*_m dm$$

Replace this result into equation 14 will obtain equation 16.

The welfare effect is then composed by three parts. The first term is the **welfare effect generated by free trade** (-mdp here). Similar to the analysis mentioned above, trade liberalization generates usually positive welfare effect. The second term denotes the **environmental effect due to domestic environmental policy** which aims to internalize the negative environmental impacts that domestic emissions engender. If domestic policy is stronger than environmental damage, domestic emission increase will generate positive welfare effect; if domestic policy internalizes the domestic environmental damage ($\gamma = \mathrm{MD_e}$), the domestic emissions will have no environmental welfare impact; if domestic policy is not sufficient ($\gamma - \mathrm{MD_e} < 0$), the domestic emissions increase will generate negative welfare impact.

The third term of equation 16 denotes **the impact of emissions of foreign countries due to the change of the pattern of trade**. Assume that foreign environmental policy is not sufficient, we have thus MDe*>0. In the case of a net importer of X, we have m>0 and e*'>0. The more the domestic country imports the good X, the higher the negative welfare effect that the foreign emissions generate. In the case of a net exporter of X, we have m<0 and e*'>0, the more X the domestic country exports, the lower the foreign country's emissions level which generate positive welfare effect to domestic country.

3.2.2 Net welfare impact of trade

The net effect of a trade increase of X under such global pollution has many possible results. Table 1 concludes possible results when foreign country's environmental policy is not sufficient. For a net exporter of X, the trade liberalization increases the export amount of X and therefore de>0 and dm<0. For a net importer of X, the trade liberalization increases the import of X and therefore de<0 and dm>0. Only in the case that the domestic country is a net exporter of X and that its environment policy is sufficient enough that the trade liberalization can generate positive impact on welfare of domestic country. Otherwise, the final welfare impact is uncertain and will depend on all trade, domestic pollution and foreign pollution effects.

As a result, **trade liberalization under the presence of global pollution does not always generate positive welfare effect and could engender negative total welfare effect due to negative environmental impact**. But indeed, the trade liberalization itself might not be blamed as a principal reason of environmental degradation. It is in fact the lack of sufficient domestic environmental policy that constitutes the key contribution to negative welfare impact.

Table 1. Total welfare effect of trade under global pollution (with insufficient foreign environmental policy)

	Trade effect $(-\mathbf{mdp})$	**Domestic pollution effect** $([\boldsymbol{\gamma} - \mathbf{MD_e}]\mathbf{de})$	**Foreign pollution effect** $(-\mathbf{MD_{e*}e_m^*dm})$	**Total welfare effect**
Net exporter of X, $\boldsymbol{\gamma} > \mathbf{MD_e}$	Positive	Positive	Positive	**Positive**
Net exporter of X, $\boldsymbol{\gamma} < \mathbf{MD_e}$	Positive	Negative	Positive	**Uncertain**
Net importer of X, $\boldsymbol{\gamma} > \mathbf{MD_e}$	Positive	Negative	Negative	**Uncertain**
Net importer of X, $\boldsymbol{\gamma} < \mathbf{MD_e}$	Positive	Positive	Negative	**Uncertain**

3.3 The contribution of border measures

In this section, we examine the role of border measures (import tariffs and export tax) under the presence of global pollution.

3.3.1 Import tax in an importing country of polluting goods

Assume that the revenue function now writes in the form of

$$I = G\left(p(1+t), K, L, e\right) + tpm \qquad (17)$$

Where t is the import tariff on X. The derivative form is then

$$dI = pxdt + \gamma de + tpdm + pmdt \qquad (18)$$

Using similar approach of 3.1.4, we obtain that

$$\frac{dV/dt}{V_I} = \left(tp - MD_{e^*} \cdot e_m^*\right)\frac{dm}{dt} + \left[\gamma - MD_e\right]\frac{de}{dt} \qquad (19)$$

For an importer of X, we have dm/dt<0 and de/dt>0: the higher the import tariff, the lower import level of X and the higher the domestic emissions due to X's domestic production increase. If the tariff level is sufficiently low at the beginning which satisfies that $tp - MD_{e^*}e_m^* < 0$, we then have $(tp - MD_{e^*}e_m^*)dm/dt > 0$. The increase of tariff level generates positive welfare effect since the externality due to foreign emissions increase can be internalized by the tariff. When $tp = MD_{e^*}e_m^*$, the environmental impact due to global trade of foreign goods is neutral. While if the initial level of tariff is high that $tp - MD_{e^*}e_m^* > 0$, the reduction of tariff can generate a positive welfare impact due to the increase of import (dm>0).

The second term of the right side of equation 19 denotes the welfare impact generated by domestic policy under global trade. If domestic policy is sufficient enough, the increase of tariff generates positive or neutral welfare impact. If domestic policy is insufficient, the increase of tariff would reduce the welfare effect and a tariff cut can engender positive welfare effect.

Table 2 enlists the total welfare impact that import tariffs generate for a net importer of X. As seen, **import tariff changes can generate positive welfare effects in two cases**: first, an increase of import tariff when the initial level of tariff is low and the domestic environmental policy is sufficient; second, a decrease of import tariff when the initial import tariff is high and the domestic environmental policy is not sufficient. Otherwise, the change of import tariff will generate opposite results from tariff and domestic pollution effects and lead to an uncertain final welfare effect.

Table A2. Welfare impact determinants of an importer of polluting good with increasing import tariffs

	Tariff effect ($(tp - MD_{e^*}e_m^*)dm/dt$)	Domestic pollution effect ($[\gamma - MD_e]de/dt$)	Total welfare effect
$tp - MD_{e^*}e_m^* < 0$ and $\gamma - MD_e < 0$	Positive	Negative	Uncertain
$tp - MD_{e^*}e_m^* < 0$ and $\gamma - MD_e > 0$	Positive	Positive	Positive
$tp - MD_{e^*}e_m^* > 0$ and $\gamma - MD_e < 0$	Negative	Negative	Negative
$tp - MD_{e^*}e_m^* > 0$ and $\gamma - MD_e > 0$	Negative	Positive	Uncertain

3.3.2 Export tax in an exporting country of polluting good

Assumes that a country is net exporter of X and it imposes t as export tax on X. The revenue function is given by

$$I = G(p, K, L, e) - tpm \qquad (20)$$

The derivative gives that

$$dI = xdp + \gamma de - tmdp - tpdm - pmdt \qquad (21)$$

Following the same approach of 3.1.4 and replace equation 21 into equation 13, we have

$$\frac{dV/dt}{V_I} = -(1+t)m\frac{dp}{dt} - \left(tp + MD_{e^*} \cdot e_m^*\right)\frac{dm}{dt} + \left[\gamma - MD_e\right]\frac{de}{dt} - pm \qquad (22)$$

Recalled that we have assumed that the tax rate changes do not have any impact on the price of goods, equation 22 can be shortened by

$$\frac{dV/dt}{V_I} = -\left(tp + MD_{e^*} \cdot e_m^*\right)\frac{dm}{dt} + \left[\gamma - MD_e\right]\frac{de}{dt} - pm \qquad (23)$$

With –pm which is constant and positive (m<0 in case of exporter and p>0). We have dm/dt>0 and de/dt<0: the higher the export tax rate on X, the lower the production level (the lower the export level) and the lower the emission level in domestic country.

Different to the case of import tariffs on X discussed above, the increase (decrease) of export tax rate generates permanently a negative (positive) welfare impact in terms of foreign emissions. As the first part of the right hand side of the equation 23 shows, it increase (decrease) of the export tax rate of domestic exporting country of X will increase (decrease) the foreign production of X and generate related emission increase (decrease).

At domestic level, the increase of export tax will generate positive welfare effect in terms of domestic emissions when domestic environmental policy is insufficient but will generate negative welfare impact when domestic environmental policy is sufficient. Table 3 and 4 enlist respectively the total welfare impact of an increasing and decreasing export tax. As seen in the case of sufficient domestic environmental policy, the increase of the export tax rate generates total welfare degradation and the decrease of export tax rate generates total welfare increase. While in the case of insufficient domestic environmental policy, the export tax rate changes generate opposite moves of welfare effects due to foreign and domestic emission changes and the final results are uncertain.

Table 3. Welfare effect of increasing export tax rate in a country of net exporter of polluting good

	Tax effect on foreign emissions ($-(tp + MD_{e*}e_m^*)dm/dt$)	Domestic policy effect ($[\gamma-MD_e]de/dt$)	Total welfare effect
Insufficient domestic policy ($\gamma-MD_e<0$)	Negative	Positive	Uncertain
Sufficiently high domestic policy ($\gamma-MD_e>0$)	Negative	Negative	Negative

Table 4. Welfare effect of decreasing export tax rate in a country of net exporter of polluting good

	Tax effect on foreign emissions ($-(tp + MD_{e*}e_m^*)dm/dt$)	Domestic policy effect ($[\gamma-MD_e]de/dt$)	Total welfare effect
Insufficient domestic policy ($\gamma-MD_e<0$)	Positive	Negative	Uncertain
Sufficiently high domestic policy ($\gamma-MD_e>0$)	Positive	Positive	Positive

3.4 Short conclusion

We have thus finished the theoretical demonstration of domestic and border carbon pricing policies under the presence of global pollutant and one developing country as net exporter of polluting good and one developed countries as net importer of polluting goods. If we assume that developed country has sufficient domestic climate policy and developing country does not implement sufficient domestic climate policy, the use of import tariff (border carbon measures) in developed countries can lead to a welfare increase, while the use of export carbon tax (or pricing) in developing country will not usually lead to welfare increase. However, it must be noted that the simple model only provides a purely theoretical description of domestic and border carbon pricing policies. To demonstrate the Chinese case in our thesis, CGE approach ensures quantifying carbon pricing policies impact on different economic and climate parameters by integrating specific Chinese market characters, while the total welfare effect will depend on the net value calculation of CO2 emissions.

4. Principles of CGE analysis

We now focus on the CGE approach and may as well start with an overview of CGE analysis. The CGE analysis is based on general equilibrium theory while is not necessarily limited to general equilibrium frameworks. Until the eighties of last century, CGE models have become an important research area and analysis measure for policy making. In general, CGE models can be divided into four major types, namely neoclassical model, elasticity structuralist model, micro and macro structuralist models. By making gradual improvements (such as introducing dynamic analysis and non-competitive market, integrating financial sector and different forms of functions, etc.), CGE models have been frequently used for vast analysis areas.

Table five enlists the principal contents of a CGE model. In the supply module, CGE model usually defines the producer behavior and optimization conditions. Most generally, the Cobb-Douglas production function and the use of Constant Elasticity of Substitution (CES) functions ensure a (partial) substitution among production factors or intermediate inputs. In an open economy, CGE models also define the partial substitution of a product between domestic and foreign markets. In the demand module, total demand can be divided into demand for final consumption, intermediate inputs and investment. The consumption is also divided into household, government and firm consumptions. Similarly to the supply module, the demand module gives the consumer behavior and maximization method. In an open economy, there is also a partial substitution between imported and domestic products.

Table 5. Basic components of CGE models

	Supply	**Demand**	**Supply and demand equilibrium**
Stakeholder	Producer	Consumer (Government, firms, households)	Market
Action	Max profits	Max utility	Equilibrium price
Equations	Production function	Utility function	Product market eq.
	Constraints	Constraints	Factors market eq.
	Optimization	Optimization	Household budget eq.
	Products supply	Goods demand	Government budget eq.
	Inputs demand	Production factor supply	International balance sheet eq.
Variables	Products price and quantity, factors price and quantity, technology; macroeconomic parameters, etc.		

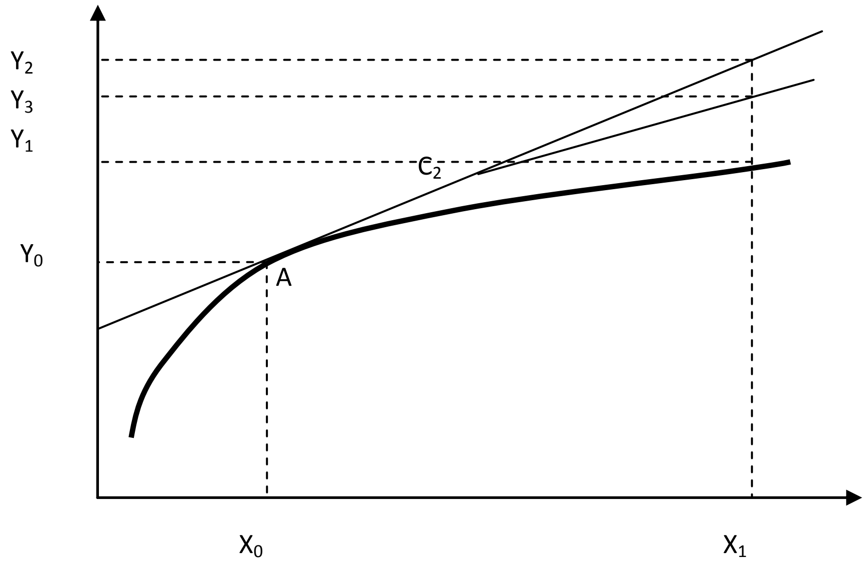
Source: Author's rearrangement based on Hu and Liu, 2009.

The supply-demand relation module defines market equilibrium conditions. Usually, a CGE model includes six equilibriums: 1) goods market equilibrium requires that total supply is equal to total demand for each product both in quantity and value. Here, a difference to the conventional GE theory is that the stock is introduced as a variable in case of difference between total supply and demand. 2) labor market equilibrium asks for equation between total labor supply and demand. If the total supply is superior to total demand for a certain period, the difference can be considered as unemployment. 3) in the short term, capital is considered rigid at sectoral level. Therefore, the short-term capital market equilibrium is sectoral-based. In the long term, capital is assumed capable to flow among sectors and therefore the long-term equilibrium requires that total capital demand of all sectors is equal to the given amount of capital. 4) investment-saving equilibrium requires that total investment is equal to total saving. The disequilibrium can be compensated by bond selling/purchasing, foreign investment or government reserve, etc. 5) the government budget equilibrium requires that total government income is equal to total government expense. In case of surplus or deficit, they can be treated as variable of government income or expense. 6) the international balance sheet equilibrium. Capital flows can be introduced as variable in case of non-zero international balance sheet.

In theory, general equilibrium requires that the six equilibriums be attained simultaneously. However, in CGE practice, such equilibrium is difficult to achieve and instead, in order to ensure the unique solution set, a commonly followed measure is to remove certain constraints or to transform a certain exogenous variable/parameter into endogenous variable in the model. Such process is usually named “macroclosure” in the CGE literature. Different macroclosure could lead to different CGE solutions. Briefly, in practice, there are two different macroclosure methods which can be called neo-classical and non neo-classical closure. The former assumes full use of factors and that the output and income are determined by producer and the latter assumes partial utilization of inputs.

The calculation approach differs among CGE models. Major methods include the Scarf method, Jacobian (also named Newton) method and the Johansen-Euler (JE) method. As the SIC-GE uses JE method, a brief introduction of JE method is given here. Figure one illustrates the JE approach. Assume that f(x,y)=0 is composed by one exogenous variable “x” and one endogenous variable “y”. The movement of X_0 to X_1 will generate a corresponding change of Y_0 to Y_1. The first order derivate of f(x,y)=0 at X_0 obtains Y_2 and will lead to a relatively large difference to Y_1. The JE approach thus makes multi-step linear calculation and could lead our result to Y_3 which is closer to Y_1. More steps like this will then sufficiently approach to a non-linear approach and significantly increase the result accuracy. In fact, such approach is adopted by the General Equilibrium Modeling Package (shortly for GEMPACK) based on which SIC-GE is calculated.

Figure 1. Illustration of Johansen-Euler approach



Source: author.

The CGE models can provide interpretable results and a discussion basis between policy analysts and policy makers. CGE models offer analyses on partial and general, direct and indirect effects of a policy with detailed sectoral decompositions. CGE models are based on GE theory but also differ from it. First, based on sectoral analysis but not directly on individuals, CGE models can provide analysis on markets with partial competition or mixed structure. Second, as mentioned above, CGE models can examine disequilibrium.

However, like all theories and practices, CGE approach also suffers from three major drawbacks or queries. First, the existence of (general) equilibrium in reality could be questioned. Second, the accuracy of CGE models is discussed. CGE models usually use base year data (or a period) to calibrate, yet the degree of representativeness falls short if the choice of base year is arbitrary. Also, the parameters and elasticity incorporated in the model are usually difficult to be tested with real statistics, therefore leaving an uncertainty on the accuracy of model results. Third, CGE models usually ignore the external cost of policy adjustment among policy scenarios, which might reduce partially the credibility of policy feasibility.

5. The SIC-GE model

5.1 General presentation

Co-developed by the State Information Center (SIC) of China and the Monash University of Australia, the SIC-GE model is used as an auxiliary tool by the Chinese government for public policy decisions. Generally, SIC-GE models have the following features:

Detailed database. The current database includes 137 sectors, assembled from China's 2002 Input-Output Table. Besides the detailed classification of industrial sectors, it also divides the agricultural sector into 16 sectors according to crop products and livestock species as defined in China's agricultural product statistical data. SIC-GE distinguishes five labor types[25] given the segmentation of China's labor markets, thus enabling the analysis to take employment impact into consideration.

Parameters. SIC-GE includes a large number of parameters designed to describe the technology improvement, changes in consumption preferences and market distortion, etc. For instance, two levels of parameters can be designed to describe the contribution of technology improvement to energy saving in industrial production: parameters on the aggregating level will show the general energy input saving by giving the output, regardless of the changes to the energy mix; and preference parameters on the second level can describe the substitution among different energy products. These two parameter types are calibrated using SIC-GE's special historical simulation, which is based on observed historical data, and is considered exogenously in this paper in policy simulations, such as for carbon pricing policy.

Flexible mechanism for policy impacts. When simulating the impact of the carbon cost in China, different cost pass-through mechanisms (forms) can be set alongside different positions of the price formation chain. This will be demonstrated in later chapters.

Modules. The core and dynamic modules of SIC-GE are based respectively on the ORANI model (Dixon et al., 1982) and the Monash model (Dixon and Rimmer, 2002). SIC-GE includes six core modules which are respectively production module, investment module, household and government consumption module, export module, price and tax module, and dynamic module. For the first five modules, the theory basis is similar to most of the CGE models. For instance, in the production module, the multi-level nested production function was applied to describe the production process in each industry. The cost minimization is used to illustrate the demand of primary inputs and intermediate inputs. For the dynamic module, there are two main equations. One describes the capital accumulations (including new investments); the other describes the net foreign liability accumulations (including the foreign liability and foreign assets).

Recursive dynamic. The dynamic impact analysis is obtained in the recursive form with the SICGE model. Two options are generally available when simulating the dynamic effect of a policy impact: firstly, a short-term analysis can be conducted, which usually requires data on the rigid real wage, capital stocks, flexible employment and the rate of capital return; and secondly, a long-term analysis is

[25] Respectively, rural agricultural worker, rural non agricultural worker, rural-urban migration worker, urban skilled worker and urban un-skilled worker.

possible using data on rigid employment, the capital return rate, the flexible real income and capital stocks. This thesis adopts the method used by Dixon and Rimmer (2002) that integrates the two options. For the labor market, the real wage figure used is quasi-rigid, while employment is defined as flexible during the first measured period of the policy impact (one year). In the year-on-year recursive form, the real wage is adjusted based on total employment changes in the former period in order to take account of such changes. The real wage adjustment terminates when the total employment returns to its baseline level. As a result, the policy impact on employment changes is zero and the real wage is flexible in the long term. For the capital market, this thesis adopts a conventional recursive dynamic: the capital stocks at the beginning of year t are equal to the capital stocks at the end of year t-1. The capital stocks at the end of year t are the sum of the capital stocks of the beginning of year t and the total investment in year t minus the depreciations in year t. In year t there is no policy impact on the capital stocks of the same year, but the expectation of the investment return rate is affected, and changes in capital stocks are therefore generated in the following year.

5.2 Energy use module

The original energy module of SIC-GE assumes that energy inputs are not substitutable and is based on annual analysis. This section presents the adjustment of the energy module in order to provide long-term analysis on CO2 emissions and energy consumption. The original production module of SIC-GE is presented by figure 2. As seen, energy is considered as capital input. Figure 3 then shows the adjustment on production module by introducing substitution among energy inputs. The adjusted production module is composed by six levels. At the first level, the output of a sector is determined by the value-added, intermediate inputs and other expenses in a Leontief function. According to equation 24, the production of a certain output requires n+2 inputs, with the n intermediate inputs, the (n+1)th input is basic production factors (capital, energy, labor and land here) and the (n+2)th input is other costs. $X_{i,j}^{(1)}$ is the input of ith product into the jth sector, $A_{i,j}$ is the corresponding technology parameter. Z_j is the total output of sector j with $A_j^{(1)}$ as the corresponding technology parameter.

$$\underset{i=1,\dots,n+2}{Leontief}\left\{\frac{X_{i,j}^{(1)}}{A_{i,j}}\right\} = A_j^{(1)} Z_j \qquad (j=1,\dots,n) \tag{24}$$

with $\underset{i=1,\dots,r}{Leontief}\{f_i\} = \min\{f_1, f_2, \dots, f_r\}$

The second level of the production module is presented by equation 25 under CES form, where EK_j, Lb_j and Ln_j denote respectively the input of energy&capital, labor and land of jth sector; $A_{EK,j}$, $A_{Lb,j}$ and $A_{Ln,j}$ are corresponding technology parameters; $b_{EK,j}$, $b_{Lb,j}$ and $b_{Ln,j}$ are corresponding share parameters with $b_{EK,j} + b_{Lb,j} + b_{Ln,j} = 1$; ρ_j^{EKLL} is the elasticity of substitution.

$$X_{n+1,j}^{(1)} = CES\left\{\frac{EK_j}{A_{EK,j}}, \frac{Lb_j}{A_{Lb,j}}, \frac{Ln_j}{A_{Ln,j}}; \rho_j^{EKLL}, b_{EK,j}, b_{Lb,j}, b_{Ln,j}\right\} \quad (25)$$

At the third level, the energy&capital compound is decomposed into energy and capital. As equation 26 shows, $X_{E,j}^{(1)}$ and K_j are respectively the input of energy and capital of jth sector with $A_{E,j}^{(1)}$ and $A_{K,j}$ as corresponding technology parameters. Similarly, $b_{E,j}$ and $b_{K,j}$ are share parameters and ρ_j^{EK} as the elasticity of substitution between energy and capital.

$$EK_j = CES\left\{\frac{X_{E,j}^{(1)}}{A_{E,j}^{(1)}}, \frac{K_j}{A_{K,j}}; \rho_j^{EK}, b_{E,j}, b_{K,j}\right\} \quad (j = 1, \ldots, n) \quad (26)$$

At the fourth level, equation 27, given in a CES form, illustrates that the energy input is decomposed into the coal&coke compound ($X_{col_{coke},j}^{(1)}$), oil products&natural gas compound($X_{oil_{pet},j}^{(1)}$), electricity ($X_{ele,j}^{(1)}$) and gas ($X_{gas,j}^{(1)}$), with related share parameters noted in "b" with corresponding indexes and the elasticity of substitution ρ_j^{E4}.

$$X_{E,j}^{(1)} = CES\left\{\frac{X_{\text{col\_cok},j}^{(1)}}{A_{\text{col\_cok},j}^{(1)}}, \frac{X_{\text{oil\_pet},j}^{(1)}}{A_{\text{oil\_pet},j}^{(1)}}, \frac{X_{\text{ele},j}^{(1)}}{A_{ele,j}^{(1)}}, \frac{X_{\text{gas},j}^{(1)}}{A_{gas,j}^{(1)}}; \rho_j^{E4}, b_{\text{col\_cok},j}^{(1)}、 b_{\text{oil\_pet},j}^{(1)}、 b_{\text{ele},j}^{(1)}、 b_{\text{gas},j}^{(1)}\right\} \quad (j = 1, \ldots, n) \quad (27)$$

At the fifth level, equations 28 and 29 decompose respectively the coal&coke compound and oil&NG compound, where $X_{col,j}^{(1)}$, $X_{cok,j}^{(1)}$, $X_{oil,j}^{(1)}$ and $X_{pet,j}^{(1)}$ denote respectively the input of coal, coke, oil and natural gas, with $A_{col,j}$, $A_{cok,j}$, $A_{oil,j}^{(1)}$, $A_{cok,j}^{(1)}$ as corresponding technology parameters, $b_{col_{cok},j}^{(1)}$, $b_{col_{cok},j}^{(1)}$, $b_{col_{cok},j}^{(1)}$ and $b_{col_{cok},j}^{(1)}$

as corresponding share parameters and ρ_j^{E4} as elasticity of substitution.

$$X^{(1)}_{\mathrm{col\_cok},j} = Leontief\left\{\frac{X^{(1)}_{\mathrm{col},j}}{A_{col,j}}, \frac{X^{(1)}_{\mathrm{cok},j}}{A_{cok,j}}\right\} \quad (j=1,...,n) \tag{28}$$

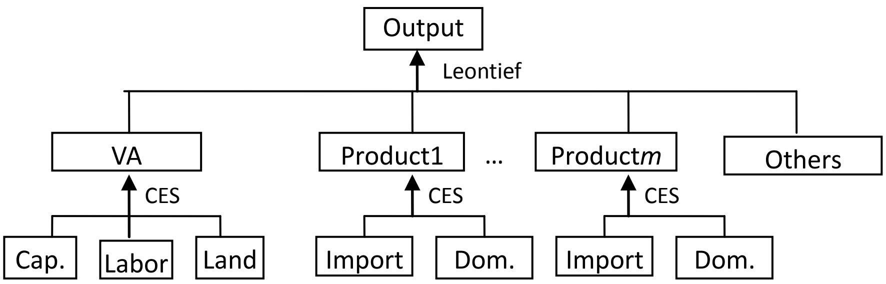
$$X^{(1)}_{\mathrm{oil\_pet},j} = CES\left\{\frac{X^{(1)}_{\mathrm{oil},j}}{A^{(1)}_{\mathrm{oil},j}}, \frac{X^{(1)}_{\mathrm{pet},j}}{A^{(1)}_{\mathrm{pet},j}}; \rho_j^{oil\_pet}, b^{(1)}_{\mathrm{oil},j}、 b^{(1)}_{pet,j}\right\} \quad (j=1,...,n) \tag{29}$$

At the sixth level, the input of energies is divided into import and domestic products and written in a CES form by equation 30, where $X^{(1)}_{(is)j}$, $A^{(1)}_{(is)j}$, $b^{(1)}_{(is)j}$ represent respectively the input of ith product from sth origin (s=1 indicates domestic product; s=2 indicates imported product) to jth sector and corresponding technology parameter and share parameter. $\rho^{(1)}_{ij}$ is the elasticity of substitution.

$$X^{(1)}_{i,j} = \underset{s=1,2}{CES}\left\{\frac{X^{(1)}_{(is)j}}{A^{(1)}_{(is)j}}; \rho^{(1)}_{ij}, b^{(1)}_{(is)j}\right\} \quad (i,j=1,...,n) \tag{30}$$

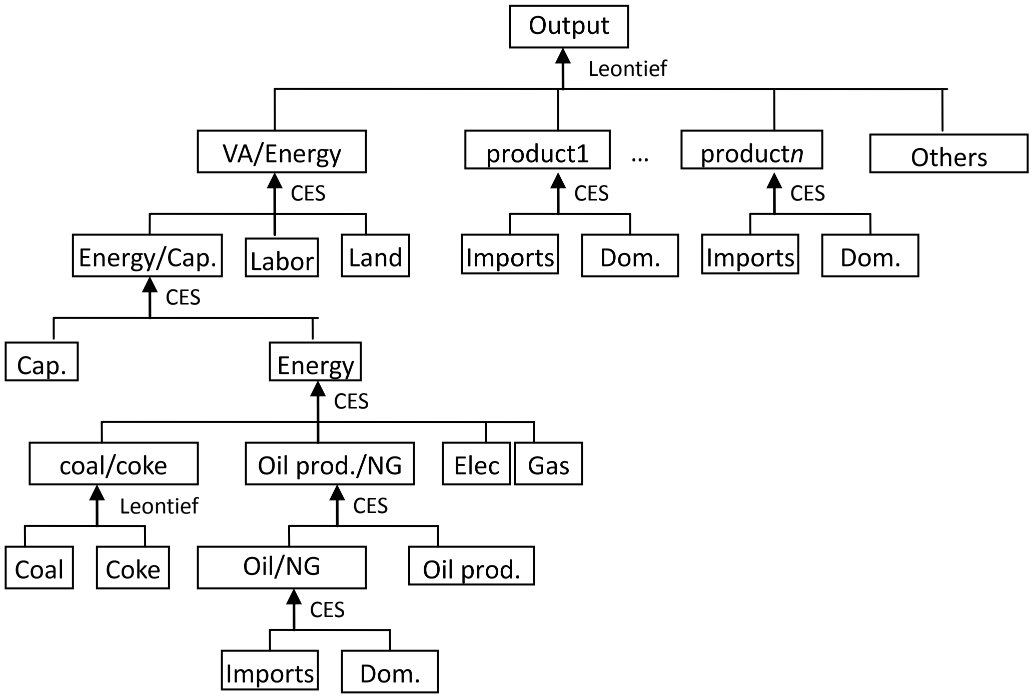
With $\underset{s}{CES}\left\{f_s;\rho,b_s\right\} = \left(\sum_s f_s^{-\rho} b_s\right)^{-(1/\rho)}$

Figure 2. Original production module of SIC-GE



Source: SIC.

Figure 3. Adjusted production module of SIC-GE



Source: SIC.

5.3 Module related to carbon pricing analysis

This section presents how the CO2 emissions from fossil fuels and from the industrial process of cement are taken into account in SIC-GE model, of which the original version of SIC-GE does not include. Two fundamental works have been made: first, a database of sectoral CO2 emissions of 2002 base year has been established (while in later analysis we have used 2007 Chinese sectoral energy consumption data for calculating CO2 emissions). Second, a module for evaluating the impact of carbon pricing policies has been created within the model. The specific carbon cost is then converted into ad valorem form on product price for each sector.

5.3.1 CO2 emissions from fossil fuel combustion and the integration of carbon pricing analysis

As will be shown in the following chapter, the Energy Statistical Yearbook (ESY) of China provides 44-sector, 18-energy-type end-use energy consumption data, which is so far the most detailed and publicly accessible database in China. The sectoral CO2 emissions due to energy combustion of the 44 sectors can be obtained by equations 31 and 32.

$$QA_{r,k}^{(1)}(2002) = \varepsilon_r \times \theta_r \times E_{r,k}^{(1)}(2002) \quad (r = 1,\ldots,18;\ k = 1,\ldots,44) \tag{31}$$

$$QA_r^{(3)}(2002) = \varepsilon_r \times \theta_r \times E_r^{(3)}(2002) \quad (r = 1,\ldots,18) \tag{32}$$

Recall that the base year of SIC-GE is 2002, $\mathrm{QA}_{r,k}^{(1)}$ is the CO2 emissions due to energy use of the rth type of energy by the kth sector which is noted $\mathrm{E}_{r,k}^{(1)}$; $\mathrm{QA}_{r}^{(3)}$ is the CO2 emissions due to the use of the rth type of energy by the household which is noted $\mathrm{E}_{r}^{(3)}$; ε_r is the CO2 emission factor of the rth type of energy (kgCO2/TJ); θ_r is the conversion factor of the heat value of a unit physical quantity of the rth energy (low heating value). Table six enlists related data.

Table 6. Related data of equations 31 and 32.

	ε_r ($kgCO_2$/TJ)[a]	θ_r (MJ/t,km^3)[b]	$\varepsilon_r\theta_r$($kgCO_2$/t,10km^3)
Raw coal	87,300	20908	1825
Washed coal	87,300	26344	2300
Other washed coals	87,300	8363	730
Briquette	87,300	20908	1825
Coke	95,700	28435	2721
Coke oven gas	37,300	16726	6239
Other gas	37,300	5227	1950
Crude oil	71,100	41816	2973
Gasoline	67,500	43070	2907
Kerosene	72,600	42652	3097
Diesel	75,500	41816	3157
LPG	61,600	50179	3091
Refinery gas	48,200	46055	2220
NG	54,300	38931	21140
Other petroleum products	75,500	41816	3157
Other coking products	95,700	28435	2721
Heat	0		0
Electricity	0		0

Source: a: IPCC, 2006; b: 2008 Energy Statistical Yearbook of China (ESY).

The SIC-GE model divides Chinese economy into 137 sectors of which six sectors are energy production and conversion sectors. In order to allocate the CO2 emissions and energy consumption calculations which are based on the most detailed and publicly available 44-sector 18-energy-type data provided by Energy Statistical Yearbook into the model, two steps have been made. First, 18 energy types are regrouped into the six energy production and supply sectors (see table seven). Second, sectoral CO2 emissions of the 137 sectors can be obtained from sectoral emissions of the 44 sectors. In the case that several sectors under the 137-sector division correspond to one sector under the 44-sector division, the sectoral CO2 emissions of the formers are obtained by using their specific energy consumption from the IO-table of SIC-GE as weight.

Table 7. Energy production and supply sectors in SIC-GE

SIC-GE model sector	Energy types in ESY
Mining and washing of coal	Ras coal, washed coal, other washed coal, briquette.
Extraction of petroleum and natural gas	Crude oil, NG.
Processing of petroleum and nuclear fuel	Gasoline, kerosene, diesel, fuel oil, LPG, other petroleum products
Processing of coke	Coke, other coking products
Production and distribution of electricity and heat power	Heat, electricity.
Production and distribution of gas	Coke oven gas, other gas, refinery gas

Source: SIC.

The CO2 emissions of the following years can be obtained by equations 33 and 34, where $Q^{(1)}_{(is),j}(t)$ is the CO2 emissions from the ith type of energy of the sth origin into the jth sector of yeat t, $Q^{(3)}_{(is)}(t)$ is the CO2 emissions of the household by using the ith type of energy with the sth origin; $x^{(1)}_{(is),j}(t)$ and $x^{(3)}_{(is)}(t)$ are respectively percentage change of related energy input of industry and household sectors.

$$Q^{(1)}_{(is)j}(t) = Q^{(1)}_{(is)j}(t-1) \times \left(1 + \frac{x^{(1)}_{(is)j}(t)}{100}\right)$$
$$(t \geq 2003;\ i = 1,\dots 6;\ s = 1,2;\ j = 1,\dots,137) \qquad (33)$$

$$Q^{(3)}_{(is)}(t) = Q^{(3)}_{(is)}(t-1) \times \left(1 + \frac{x^{(3)}_{(is)}(t)}{100}\right) \quad (t \geq 2003;\ i = 1,\dots 6;\ s = 1,2) \qquad (34)$$

Finally, the impact of carbon price is integrated into the SIC-GE model by the following equations. Firstly, equations 35-36 transform the specific carbon price, noted as "CTAX" (yuan/tCO2) into ad valorem tax on energy inputs, where $R^{(1)}_{(is),j}$ is the ad valorem carbon price rate (yuan/yuan) of the input of ith type of energy with the sth origin into the jth sector; $R^{(3)}_{(is)}$ is the ad valorem carbon price rate of the household use of the ith type of energy with the sth origin; $P^{(1)}_{(is)j}$, $X^{(1)}_{(is)j}$, $P^{(3)}_{(is)}$ and $X^{(3)}_{(is)}$ are related base price and input quantity of energy.

$$CTAX \times Q^{(1)}_{(is)j} = R^{(1)}_{(is)j} \times \left(P^{(1)}_{(is)j} \times X^{(1)}_{(is)j}\right)$$
$$(i=1,\ldots 6;\ s=1,2;\ j=1,\ldots,137) \qquad (35)$$

$$CTAX \times Q^{(3)}_{(is)} = R^{(3)}_{(is)} \times \left(P^{(3)}_{(is)} \times X^{(3)}_{(is)}\right)$$
$$(i=1,\ldots 6;\ s=1,2) \qquad (36)$$

In order to provide facility to the GEMPACK calculation, equations 35 and 36 can be further transformed into linear form. As shown by equations 37 and 38, Δ CTAX is the change of carbon price level (yuan/tCO2); $R1^{(1)}_{(is),j}$ and $R1^{(3)}_{(is)}$ are the level of ad valorem carbon price (yuan/yuan); $R2^{(1)}_{(is),j}$ and $R2^{(3)}_{(is)}$ are total tax level before the implementation of a carbon price; $r2^{(1)}_{(is),j}$ and $r2^{(3)}_{(is)}$ are the change of total tax level after the implementation of a carbon price (%); $p^{(0)}_{(is)j}$ and $p^{(0)}_{(is)}$ are the change of the base prices in SIC-GE model (%).

$$100\Delta CTAX \cdot Q^{(1)}_{(is)j} = (R2^{(1)}_{(is)j}+1)\cdot(P^{(1)}_{(is)j}\cdot X^{(1)}_{(is)j})\cdot r2^{(1)}_{(is)j} + R1^{(1)}_{(is)j}\cdot(P^{(1)}_{(is)j}\cdot X^{(1)}_{(is)j})\cdot p^{(0)}_{(is)j}$$
$$(i=1,\ldots 6;\ s=1,2;\ j=1,\ldots,137) \qquad (37)$$

$$100\Delta CTAX \cdot Q^{(3)}_{(is)} = (R2^{(3)}_{(is)}+1)\cdot(P^{(3)}_{(is)}\cdot X^{(3)}_{(is)})\cdot r2^{(3)}_{(is)} + R1^{(3)}_{(is)}\cdot(P^{(3)}_{(is)}\cdot X^{(3)}_{(is)})\cdot p^{(0)}_{(is)}$$
$$(i=1,\ldots 6;\ s=1,2) \qquad (38)$$

5.3.2 Cement process emissions and the integration of carbon price analysis

So far, the industrial process CO2 emissions database is not complete and not publicly accessible in China. Given data availability and the significance of process emissions relative to total emissions of each product, only the process CO2 emissions of cement production is taken into account and adjusted to the SIC-GE model for the thesis.

Table eight enlists process CO2 emissions of cement production in China obtained by mainstream studies. As seen, the Process CO2 emission level for a ton of cement in China ranges between 0.098 to 0.137 ton of carbon and three studies among total four studies have provided similar results (around 0.1 tC/t cement). Therefore, we adopt this level (equivalent to 0.37 tCO2/t). In 2002, the cement production in China reached to 725 million tons. We then obtain the process CO2 emissions of cement 268.3 million tons CO2 for the base year of SIC-GE model.

Table 8. Results of CO2 emissions from cement production in China

Authors	CO2 emissions due to energy use （tC/t）	Process emissions （tC/t）
Zhu (2001)	0.100～0.108（0.103）	0.098～0.100（0.099）
Mao et al. (2004)	0.082～0.123	0.099
Office of national climate change coordination group (2004)	N/A	0.102
Feng and Chen (2003)	0.093～0.108（0.101）	0.137

Source: author's rearrangement.

Similarly, the process CO2 emissions of cement of the following years can be obtained by equation 39, where $QP_{cem}(t)$ is the process CO2 emissions of cement in year t and $x_{cem}(t)$ is the percentage change of cement output of year t.

$$QP_{cem}(t) = QP_{cem}(t-1) \times \left(1 + \frac{x_{cem}(t)}{100}\right) \quad (39)$$

Finally, the impact of carbon price on the use of energy for cement production has been demonstrated by the previous section. Equation (40) illustrates how the impact of carbon price on cement process emissions can be integrated into the SIC-GE model. $QP_{cem}(t)$ is the process CO2 emissions of cement, T_{cem} is the ad valorem carbon price relative to process emissions (in the form of a production tax) and $V1CST_{cem}$ is the total production cost of cement, which is a parameter of the SIC-GE model.

$$CTAX \times QP_{cem} = T_{cem} \times V1CST_{cem} \quad (40)$$

Transform the equation 40 into the linear form for GEMPACK calculation, we obtain equation 41, where $V1TOT_{cem}$ is the total revenue after tax of cement sector; ΔPTX_{cem} is the change of the production tax of cement sector; $V1PTX_{cem}$ is the total production tax revenue collected from cement sector and $p1tot_{cem}$ is the percentage change of the average sale price of cement sector.

$$100 \times QP_{cem} \times \Delta CTAX = \frac{100 \times V1TOT_{cem} \times \Delta PTX_{cem}}{(1+PTX_{cem})^2} + V1PTX_{cem} \times p1tot_{cem} \qquad (41)$$

5.4 Export module

The SICGE model's export module comprises two equations: the export demand and the free on board (FOB) prices of export products. The export demand x_i^{FR} given by equation (42) is given as a function of the FOB price of the export products (see Dixon and Rimmer (2002) for details)

$$x_i^{FR} = \theta_i \left[pex_i^{FOB} - fep_i\right] + feq_i + feq_g \qquad (42)$$

where x_i^{FR} is the percentage change in the export demand of product i, θ_i is the foreign demand price elasticity of product i, pex_i^{FOB} is the FOB price of product i, fep_i and feq_i and feq_g are respectively the parameters of vertical and horizontal changes of the export demand curve.

The FOB price of an exported product i is given by equation (43)

$$VEX_i^{FOB}\, pex_i^{FOB} = \left[VEX_i^{bas} + VTEX_i\right] \times \left(pex_i^{bas} + t_i^{EX}\right) + \sum_m VMAR_{m,i}^{EX} \times (p_m^{dom}) \qquad (43)$$

where, for a product i, VEX_i^{FOB}, VEX_i^{bas}, $VTEX_i$ and $VMAR_{m,i}^{EX}$ are parameters which denote respectively the value calculated according to the FOB price (domestic currency), the base price (production cost), the total tax revenue and the mth margin cost. For variables given in the form of percentage change in equation (42), pex_i^{FOB} is the FOB price, pex_i^{bas} is the base price, t_i^{EX} is the power of the tax rates[26] (including export tax rate changes) and p_m^{dom} is the base price of the mth margin.

According to equation (43), the export FOB price of product i is a weighted average of manufacturer price and costs. The manufacturer price is the sum of the base price and the tax costs (including the export tax). The policy impact is obtained by modifying the export tax rates t_i^{EX} as will be shown in later analyses.

6. Conclusion

We have demonstrated a simplified theoretical model with domestic and border carbon pricing policies and provided detailed explanation on energy-climate and trade modules of the SIC-GE model in this chapter. First, according to the simple two

[26] E.g. if the tax rate is 20% for a given sector, the power is 1+20%=120%.

countries, two goods and one pollutant general equilibrium theoretical model, the general welfare effect is determined by three components: free trade, the level of domestic climate policy and the level of climate policy of foreign country. Free trade always generates welfare increasing other things being equal, while the lack of stringent climate policy can lead to general welfare loss in a world of trade and unequal carbon prices. For example, in case that a domestic country's climate policy is sufficient, the welfare effect of border carbon pricing policies will depend on trade position (net exporter or importer of the polluting good) of the domestic country and the climate policy stringency of the foreign country. If we consider the domestic country having stringent domestic climate policy and being a net importer of the polluting good (a typical developed country case), and the foreign country having insufficient domestic climate policy and being a net exporter of the polluting good, both import carbon pricing in domestic country and export carbon pricing in foreign country can lead to general welfare increase. This ensures a comprehensive understanding of the interaction between domestic and border carbon pricing policies.

Second, given that the focus of the thesis lays on China's carbon pricing policies, we will need a modeling analysis which includes detailed sectoral divisions and sufficient Chinese market contexts. This is why the SIC-GE model which serves for policy making of Chinese central government is chosen as policy simulation tool. It both provides solid scientific basis and ensures the result credibility at policy making level. In order to ensure a clear SIC-GE model results interpretation in later chapters, we have shown how the energy-climate module and trade module works in the SIC-GE model. As seen, SIC-GE includes so far the most detailed energy and CO_2 emissions data in China, which makes it an advantage in accuracy.

Certainly, the CGE analysis does not necessarily always provide the most accurate results and indeed, neither model can achieve this. However, the results obtained by SIC-GE analysis do serve as a good reference for policy making. Yet, the policy decision could and should not merely rely on modeling analysis. This is why the thesis has also adopted non-CGE quantitative and qualitative approaches together with CGE analysis in order to provide a detailed and a complete basis for policy analysis and recommendations.

References:

Allais, M., 1943. *A la recherche d'une discipline économique*. Première partie. L'économie pure. Réédité sous le titre : Traité d'économie pure, Imprimerie Nationale, Paris.

Arrow, K., Debreu, G., 1954. Existence of an equilibrium for a competitive economy, *Econometrica* 22, pp.265-290.

Bhagwati, J.N., 2004. *Free Trade Today*, Princeton University Press, Princeton and Oxford.

Bhagwati, J.N., Panagariya, A., Srinivasan, T.N., 1998. *Lectures on International Trade*, 2nd Eds., The MIT Press.

Copeland, B.R., Taylor, M.S., 2009. Trade, tragedy and the commons, *American Economic Review*, 99(3), pp.725-749.

Copeland, B.R., Taylor, M.S., 2005. Free trade and global warming: a trade theory view of the Kyoto Protocol, *Journal of Environmental Economics and Management*, 49(2), pp.205-234.

Copeland, B.R., Taylor, M.S., 2004. Trade, growth and the environment, *Journal of Economic Literature*, 42, pp.7-71.

Copeland, B.R., Taylor, M.S., 2003. *Trade and the environment, theory and evidence*, Princeton University Press, Princeton and Oxford.

Dai, H., Masui, T., Matsuoka, Y., Fujimori, S., 2011. Assessment of China's climate commitment and non-fossil energy plan towards 2020 using hybrid AIM/CGE model, *Energy Policy* 39, pp.2875-2887.

Dixon, P.B., Parmenter, B.R., Sutton, J., and Vincent, D.P., 1982. *ORANI: A Multi-sectoral Model of the Australian Economy*, North-Holland, Amsterdam.

Dixon, P.B., Rimmer, M.T., 2002. Dynamic General Equilibrium Modeling for Forecasting and Policy. North-Holland. P88, 243.

Feng, B.X., Chen, J.R., 2003. Cement sector CO_2 emissions reduction of Taiwan, *Fu Jian Environment*, 2003 20(01), pp.16-19. (in Chinese)

Hanh, F., 1984. *Equilibrium and Macroeconomics*, Basil Blackwell, Oxford.

Hicks, J., 1939. *Value and Capital: An Inquiry into Some Fundamental Principles of Economic Theory*, 2nd Ed., Oxford University Press, New York.

Hu, Z., Liu, W., 2009. *CGE model in energy taxation and exchange rates*, Hunan University Press, Hunan.

Jiang, K.J., Hu, X.L., Deng, Y.Y., Zhuang, X., Liu, H., Liu, Q., Zhu, S.L., 2009. Impact of carbon tax and analysis on related issues, in: Hu, X.L., Wang, J.Z., Cen, L.Y., Lei, H.P. (Eds), *2050 China Energy and CO_2 Emissions Report*. Science Press, Beijing, pp. 413-445. (in Chinese)

Kirman, A., 1989. The intrinsic limits of modern economic theory: the emperor has no clothes, *The Economic Journal* 99, pp.126-139.

Liang, Q.M., Fan, Y., Wei, Y.M., 2007. Carbon taxation policy in China: how to protect energy-and-trade-intensive sectors? *Journal of Policy Modeling*, 29, pp.311-333.

Lv, Z.D., Guo, J.E., Xi, Y.M., 2009. Econometric Estimate and Selection on China Energy CES Production Function, *China Population Resources and Environment*, 2009 (04), pp.156-160. (in Chinese)

Lallement, J., 2000. Prix et équilibre selon Léon Walras, in Béraud, A, Faccarello, G., Eds, *Nouvelle Histoire de la Pensée Economique*, Tome II, La Découverte, Paris, pp.449-497.

Mao, R.F., Fang, M.X., Mai, G.W., 2004. Waste management and CO2 emissions of cement sector, *Research of Renewable Energy*, 2004(04), pp.32-37. (in Chinese)

Mao, S.L., 2001. CO_2 emissions in cement sector and emission reduction measures, *China Energy* 2001(07), pp.32-37. (in Chinese)

Office of National Climate Change Coordination Group, 2004. *Initial National Communication of Climate Change,* China Planning Press, Beijing.

Samuelson, P., 1947. *Foundations of Economic Analysis*, Harvard University Press, Cambridge.

Wang, C., 2003. Ph.D thesis of Chinese climate policy simulation and assessment based on dynamic CGE modeling approach, Tsinghua University, Beijing. (in Chinese)

Wang, J.N., Yang, G., Jiang, K.J., 2009. Carbon tax policy study in China, *China Environment and Science*, 2009(01), pp.101-105. (in Chinese)

Ye, R., von Weizsacker, E.U., 2009. Economic instrument for energy efficiency and the environment, *China Council for International Cooperation on Environment and Development (CCICED) Policy Research Report*, Beijing, 2009.

Zhu, S., 2001. Green house gases emissions and reduction in cement sector, *China Energy* 2001(07), pp.25-28. (In Chinese)

Zylbergerg, A., 2000. La théorie de l’équilibre général de 1918 à 1938, in Béraud, A, Faccarello, G., Eds, *Nouvelle Histoire de la Pensée Economique*, Tome III, La Découverte, Paris, pp. 162-191.

Appendix A. Framework and solution of a simple general equilibrium model

A brief presentation of a simple GE framework is given in this section. It assumes that two countries (or two regions within a country) (A and B) consume and exchange two products (1 and 2). The production module is excluded for simplicity. The initial quantity of ith product (i=1,2) possessed by rth country (r=A,B) is noted as X_{ir}. Assume that the preference of consumers is identical between two countries and it can be written by an utility function with constant elasticity of substitution (CES) for a given country,

$$U = \left(\sum_i \delta_i C_i^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} \qquad \text{(A1)}$$

Where U is the utility, C_i is the consumption of ith product, δ_i is the share of ith product, with $0<\delta_i<1$, $\sum_i \delta_i=1$. σ is the elasticity of substitution between two products.

The revenue and product price of rth country is given by

$$Y_r = P_1 C_{1r} + P_2 C_{2r} \qquad \text{(A2)}$$

Where P denotes the market price of related product.

The problem for the consumer of rth country is to maximize their utility function by solving:

$$\text{Max } U_r = \left(\delta_1 C_{1r}^{\frac{\sigma-1}{\sigma}} + \delta_2 C_{2r}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}}$$
$$\text{s.t. } Y_r = P_1 C_{1r} + P_2 C_{2r} \qquad \text{(A3)}$$

The Lagrangian formula can be written as

$$L_r = \left(\delta_1 C_{1r}^{\frac{\sigma-1}{\sigma}} + \delta_2 C_{2r}^{\frac{\sigma-1}{\sigma}}\right)^{\frac{\sigma}{\sigma-1}} + \lambda(Y_r - P_1 C_{1r} - P_2 C_{2r}) \qquad \text{(A4)}$$

The first-order derivative helps to obtain the consumption demand of ith product of rth country.

$$C_i = \frac{Y}{P_i} \frac{\delta_i^{\sigma} P_i^{1-\sigma}}{\delta_1^{\sigma} P_1^{1-\sigma} + \delta_2^{\sigma} P_2^{1-\sigma}} \qquad \text{(A5)}$$

In equilibrium, the supply of the two products is equal to the demand,

$$X_{iA} + X_{iB} = C_{iA} + C_{iB} \qquad \text{(A6)}$$

Therefore, equations A2, A5, A6 compose the basic framework of the simple GE model. Eight equations and eight endogenous variables (Y_r, C_{ir}, P_i) allows solving the GE framework. For example, letting P_2=1 as numéraire, it can be obtained that

$$P_1 = \frac{\delta_1}{\delta_2}\left(\frac{X_{2A}+X_{2B}}{X_{1A}+X_{1B}}\right)^{\frac{1}{\sigma}} \qquad \text{(A7)}$$

Setting, for example, $\delta_1 = \delta_2 = 0.5$, $\sigma = 2$, X_{1A}=0.85, X_{2A}=0.15, X_{1B}=0.15, X_{2B}=0.85, it can be obtained that P_1=1, C_{1A}=0.5, C_{2A}=0.5, C_{1B}=0.5, C_{2B}=0.5, Y_A=1, Y_B=1 which is a solution set of the simple GE framework.

Appendix B. Framework of a typical Heckscher-Ohlin model

Heckscher-Ohlin (H-O) model is introduced and named after two Swedish economists E. Heckscher and B. Ohlin. H-O is adopted to present the neo-classical economic theory of the factor difference as a result of international trade in comparison with the classical economic theory of comparative advantage originated from Ricardo. This section provides the framework of a basic one country (open economy), two factors and two products (namely 1x2x2) H-O model and presents the resolution. Different to the simple model presented above, such models include production activity that is usually given in a CES form, where for the ith product, A_i is the technology parameter, ω_i is the share of capital K and labor, γ_i is the elasticity of substitution (equation B1). Following the same mathematical strategy for solving the minimization of production cost under the constraint of production technology, Box B1 gives the general framework for solving H-O GE model.

$$X_i = A_i\left(\omega_i K_i^{\frac{\gamma_i - 1}{\gamma_i}} + (1-\omega_i) L_i^{\frac{\gamma_i - 1}{\gamma_i}}\right)^{\frac{\gamma_i}{\gamma_i - 1}} \qquad \text{(B1)}$$

Box. B1. Framework of a 1x2x2 H-O model. (i=1,2)

1. the demand of ith product

$$C_i = \frac{Y}{P_i}\frac{\delta_i^{\sigma}P_i^{1-\sigma}}{\delta_1^{\sigma}P_1^{1-\sigma}+\delta_2^{\sigma}P_2^{1-\sigma}}$$

2. the zero-profit condition of ith sector

$$P_i = rk_i + wl_i$$

3. the capital demand of unit output of ith sector

$$k_i = \frac{1}{A_i^{1-\gamma_i}}\left(\omega_i\frac{P_i^F}{r}\right)^{\gamma_i}$$

4. the labor demand of unit output of ith sector

$$l_i = \frac{1}{A_i^{1-\gamma_i}}\left((1-\omega_i)\frac{P_i^F}{w}\right)^{\gamma_i}$$

Where $P_i^F = \left({\omega_i}^{\gamma_i}r^{1-\gamma_i} + (1-\omega_i)^{\gamma_i}w^{1-\gamma_i}\right)^{\frac{1}{1-\gamma_i}}$

5. Capital market equilibrium condition

$$K = k_1X_1 + k_2X_2$$

6. Labor market equilibrium condition

$$L = l_1X_1 + l_2X_2$$

7. Consumer income

$$Y = rK + wL + e\sum_i t_iP_i^w|E_i|$$

Where e is exchange rate,

8. domestic market price of ith product, t_i is the import tariffs, P_i^w is the world market price.

$$P_i = (1+t_i)P_i^w e$$

9. Import/export supply/demand of ith product

$$E_i = X_i - C_i$$

10. External trade equilibrium

$$P_1^wE_1 + P_2^wE_2 = 0$$

Appendix C. Framework of a simple Armington GE model

Comparing to the standard "textbook" model and the neo-classical H-O model presented above, Armington model is widely adopted for practical analysis by most of the CGE models developed in last couples of decades. The core difference to neo-classical models is that Armington model is based on the Armington assumption, that is, one country can import and export a same product of a sector. The differentiation of a same product by origin of production makes Armington model very applicable to analysis based on real trade data. This section provides a very simple framework of Armington model: a two country one product model (2x1 model). The utility function of the rth country (r=A,B) can be written in a CES form,

$$U_r = \left(\alpha_r D_r^{\frac{\sigma_r - 1}{\sigma_r}} + (1-\alpha_r) M_r^{\frac{\sigma_r - 1}{\sigma_r}}\right)^{\frac{\sigma_r}{\sigma_r - 1}} \qquad \text{(C1)}$$

Where D_r and M_r are respectively the demand for domestic and imported product of the rth country, α_r and σ_r are respectively share parameter and elasticity of substitution between D_r and M_r.

Following the standard solution presented in 2.1 of maximizing consumer utility under revenue constraint and using the same letters for presenting related variables, Box C1 gives the framework of a 2x1 Armington model. It includes four exogenous variables (X_r, t_r) and ten endogenous variables. The solution of this simple framework can be done easily. For example, let X_r=1, σ_r=2 and α_r =0.5, the equilibrium can be obtained with P_r=1, M_r=D_r=0.5.

Box C1. Framework of a 2x1 Armington model

1. Demand of domestic product of the rth country

$$D_r = \frac{Y_r}{P_r} \frac{\alpha_r^{\sigma_r} P_r^{1-\sigma_r}}{\alpha_r^{\sigma_r} P_r^{1-\sigma_r} + (1-\alpha_r^{\sigma_r}) P_{rm}^{1-\sigma_r}} \quad \text{, r=A,B}$$

2. Demand of imported product of the rth country

$$D_m = \frac{Y_r}{P_{rm}} \frac{(1-\alpha_r^{\sigma_r}) P_{rm}^{1-\sigma_r}}{\alpha_r^{\sigma_r} P_r^{1-\sigma_r} + (1-\alpha_r^{\sigma_r}) P_{rm}^{1-\sigma_r}} \quad \text{, r=A,B}$$

3. Consumer revenue of rth country

$Y_r = P_r X_r + t_r P_s M_s$, r=A,B and r$\neq$s, t_r is the import tariffs.

4. Domestic price of imported products from the sth country of the rth country

$P_{rm} = P_s(1+t_r)$, r=A,B and r$\neq$s

5. Market equilibrium of the rth country

$X_r - D_r = M_s$

Chapter Two. Data presentation and adjustment[27]

1. Introduction

China's statistical system is currently incomplete and occasionally generates ambiguities. For example, the recent debate between the National Bureau of Statistics of China (NBS) and the International Energy Agency (IEA) on whether China was the biggest energy consumer in 2009 (IEA, 2009; NBS, 2010a; Oster and Swartz, 2010) has underlined the importance of using comprehensive statistical data both for academic research and policy making (Sinton, 2001). **A transparent, publicly accessible and comprehensive statistical data source could contribute towards a better understanding of China** (Xu, 2004). Therein lays a twofold advantage: first, it would provide a clear decision-making basis for public policies and could help increasing administrative efficiency; second, it could deliver policy transparency and consolidate global CO_2 emission mitigation actions.

In recent years, many studies on energy or CO2 emissions issues of China involved quantitative analysis (for example, Chai et al., 2009; Ma et al., 2009; Yang, 2008; Fan et al., 2007; Liao et al., 2007) or institutional and legislative research (for example, Yu, 2010; Hu, 2007), while treating the related statistical data as a given. Of the statistical literature, there are a certain number of studies focusing on China's energy statistics (for example, Sinton, 2001; Sinton and Fridley, 2001, 2000) and GDP statistics (for example, Cai, 2000; Rawski, 2001a, 2001b; Adams and Chen, 1996; Keidel, 2001; Holtz, 2003a, 2003b; Xu, 2004). Zhang (2010) demonstrated China's statistical improvement both on energy and GDP. These studies have provided a better understanding of Chinese statistical system and ensure a clearer interpretation of results obtained from Chinese data.

This chapter presents GDP (value-added), energy, trade as well as other data used in the thesis. It has **two purposes** and provides **one particular added value**. For the purposes, it makes an update of the performance of Chinese statistical system and reviews the improvements and drawbacks. It then identifies the compatibility and incomparability of Chinese data vis-a-vis international standards in order to provide a clear basis for result interpretation. For the added value, the objective is based on the fact that the publicly available data of sectoral total energy consumption (by fossil fuel types) in China does not separate intermediate use from sectoral final consumption of primary energies (crude oil and coal particularly). This might cause double counting problem when calculating sectoral energy consumption and CO2 emissions. However, so far, little study has explicitly demonstrated such inconvenience. This chapter provides therefore a method which allows separating such intermediate primary energy use and provides an adjusted sectoral total energy

[27] This chapter contains a paper accepted for publication at **Energy Policy**: Wang, X., 2011, On China's energy intensity statistics: toward a comprehensive and transparent indicator. doi:10.1016/j.enpol.2011.08.050

consumption, which can be important not only for the accuracy and transparency of the results of this thesis, but also for other studies using sectoral energy consumption data of China.

This chapter is organized as follows: Part Two presents China's national account system; Part Three reviews the improvement and drawbacks of China's GDP and energy statistical system; Part Four explains related GDP data used in the thesis; Part Five introduces the method for adjusting sectoral energy total consumption data mentioned above; Part Six gives CO2 emission factors and explains the definition of total and sectoral CO2 emissions used by the thesis; Part Seven introduces trade data before concluding.

2. National account system evolution

National account is the framework based on statistics. Two major national account systems existed: Material Product System (MPS) was adopted by countries with planning economy, such as the Soviet Union, former eastern European countries and China during the last quarter of 20^{th} century. MPS was gradually replaced by System of National Account (SNA) as countries with planning economy transited into market economy at the end of last century. Detailed comparison of the two systems is provided in Appendix A. China's national account system has achieved a transformation from MPS to SNA from 1993. Appendix B provides details on China's national account system reform. Also, an explanation of current national account system in China is provided by Appendix B. In general, the current national accounting system is not yet mature and more efforts are and should be done in order to improve the general performance.

3. Statistical performance improvements and drawbacks

3.1 Statistical performance improvement

During the last couple of years, China has improved dramatically statistical performance. As Appendix C shows, China has accomplished complete statistical standards by 2010. Its statistical transparency, reporting processes as well as other statistical standards have also been ameliorated (See Appendix D for details). In addition, China has made several reforms in order to improve its local government statistical quality (See Appendix E for details). Particularly, energy statistics follows the same trend of general statistical performance improvement and has achieved several important improvements of data comprehensibility, reporting, etc. which are shown in Appendix F.

3.2 Remaining statistical differences and/or drawbacks

Despite the great statistical performance improvement achieved in China, many statistical reforms and norms were introduced very recently and some statistical drawbacks still exist. The clarification of such drawbacks is essential in order to provide a comprehensive interpretation of analytical results obtained from official data of China. In this section, potential statistical differences and/or drawbacks of

Chinese data used in this thesis is explained with a reference to international and/or OECD statistical standards. This would help understanding the extent of comparability of results obtained in this thesis.

3.2.1 GDP accounting approach

GDP is accounted in the form of value-added both at production and consumption side and at constant and current price (See Appendix G for details). Production GDP (production side) and expenditure GDP (consumption side) are calculated (or estimated) separately in China. As a result, discrepancy can be found on GDP (see table 1) and its growth rates (Keidel, 2001). As the degree of difference in recent years becomes far larger than the average of 0.9% during 1991-1997, it could be important to set up a framework which estimates simultaneously both GDP with an input-output or supply-use framework as OECD countries do in order to eliminate data discrepancy between these two approaches. So far, NBS considers GDP at production side more reliable and use production GDP for other related calculation, for example, the energy-intensity target mentioned in chapter one.

Table 1. Current price GDP by production approach and expenditure approach (billion yuan)

	GDP production approach	GDP expenditure approach	Difference (%)
2005	18321.74	18869.21	2.99
2006	21192.35	22165.13	4.59
2007	25730.56	26309.38	2.25
2008	30067.0	30685.98	2.06

Source: 2009 Statistic Yearbook of China (SY).

3.2.2 Sectoral GDP and the Input-Output table of China

The thesis requires using sectoral GDP. However, the most detailed sectoral GDP (44 sectors) data provided by SY contains only partial sectoral GDP data: only above-designated-size firms' GDP[28] is provided for each sector. In general, this represents a dominant share of sectoral GDP but is not statistically compatible to sectoral energy consumption data if we calculate sectoral energy/carbon intensity. Fortunately, the Input Output (IO) table of China provides complete sectoral GDP and gross value data and therefore is used by thesis. IO tables can both be presented in real (quantity) term and value (monetary) term. In China, competitive IO table[29] is released each five year and the latest IO table is published in 2007. Figure one illustrates the IO table (value form) structure.

However, in terms of statistical comparability, one fact of sectoral GDP data may

[28] A firm is above designated size if its annual turnover is superior to 5 million yuan.
[29] Given that the intermediate use does not distinguish imports and domestic products, this kind of IO table is usually called competitive IO table. To the contrary, the IO table which separates domestic and imported intermediate uses is named non-competitive IO table.

need to be highlighted. SNA defines that the basic statistical unit is “establishment” for a given activity to be accounted. In China, however, the current statistical basis is enterprise. No matter how many activities it engages, it is classified to one industry sector according to its principal activity. For example, a coal mining firm may pursue real estate investment, while all value-added from investment of real-estate will be accounted as “coal mining”. This implies that sectoral GDP may be overestimated for some sectors and underestimated for other sectors despite the fact that no impact is generated on total GDP (Xu, 2008).

Figure 1. Input-Output table structure of China.

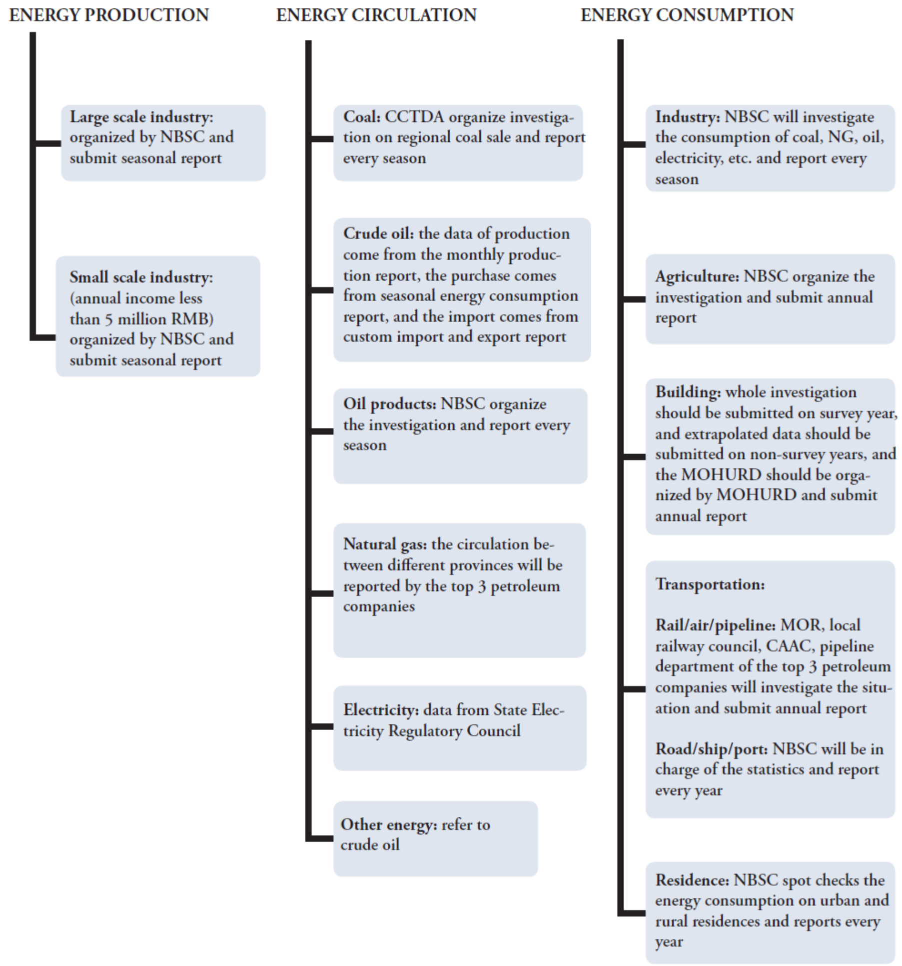
OUTPUT / INPUT		Intermediate Use				Final Use											Imports	Errors	Gross Output
						Final Consumption					Gross Capital Formation			Exports	Total Final Use				
						Household Consumption			Government	Total Final Consumption									
		Agriculture	…	Public administration and other sectors	Total intermediate use	Rural	Urban	Sub-total			Gross fixed capital formation	Change in inventories	Sub-total						
Intermediate Inputs	Agriculture	intermediate transaction				final demand													
	…																		
	Construction																		
	…																		
	Public administration and other sectors																		
	Total Intermediate Inputs																		
Value Added	Depreciation of fixed capital	primary input																	
	Compensation of employees																		
	Net taxes on production																		
	Operating surplus																		
	Total Value Added																		
Total Inputs																			

3.2.3 Energy statistics

3.2.3. 1 Energy Accounting approaches

Figure two gives related data source of different energy accountings in China. Given that the thesis majorly assesses the industrial (including electricity) sectors and does not focus on energy consumption of building and transport, only energy consumption accounting which is the principal data source used in the thesis is presented in this part. The total energy consumption is available at each year’s energy balance sheet (EBS) (see Appendix H) as well as other sources such as SY or NBS communiqués, etc. Energy consumption is accounted by production and consumption approaches in China. Production approach is used to sum primary energy production, net export and net stock changes and is usually adopted for trimester and preliminary annual data for simplicity. Consumption approach sums final energy consumption, net loss during energy transformation and loss during energy transportation and management (but excludes the loss of various kinds of gas due to gas discharges and stocktaking) and is usually adopted for annual data accounting for its complexity.

Figure 2. Data source of energy in China



Source: Teng et al., 2009.

3.2.3.2 Total and sectoral energy consumption

The final energy consumption in China combines not only end-use energy consumption but also own consumption and energy loss from energy production (or processing) industries. The non-production energy use of fossil fuels is included into final energy consumption too in China while they are usually separated in international standard. This increases artificially both China's total energy consumption and final consumption although the impact may be small. Table two compares the final energy consumption of China from different statistical sources. As seen, divergence exists (majorly) as a result of statistical approaches difference.

At sector level, similar to GDP statistics, the energy end use is reported by firms while not based on activity. Real sectoral energy consumption could thus differ from what is defined by international standard, particularly in steel sector where big enterprises are usually mini cities which provide many kinds of activities then merely steel production (Price et al., 2002). A short period of test which required that firms report their energy consumption by purpose (1992-1994) was quickly abolished for reasons of not to overcharge the firms' statistical reporting burden. Actual Chinese sectoral energy consumption still includes a certain amount of energy consumption belonging to other sectors although the statistical impact may be minimal (Sinton and Gridley, 2001).

Also, the energy consumption of certain sectors is not comparable to international standard. For instance, transport sector only includes vehicles of transportation firms and exclude vehicles for private use and of other sectors. It does not separate the transportation types such as airline, railway, road, etc. Real supply value for heat and power plants sector is not available since the actual energy statistics does not distinguish own energy use from total energy supply. Hydro and nuclear power sector is placed into the primary energy supply module and noted by electricity production. However, there is no primary input of hydro and nuclear power value which complicates the comparison of primary energy supply data with international standard.

Table 2. Final energy consumption from different sources

	LBL	**IEA**	**NBS**
1990	917.18	942.89	957.14
1995	1243.65	N/A	1242.52
2004	1976.78	1500	1941.04
2005	2211.51	1612.86	2144.79
2006	2442.23	1735.71	2351.14
2007	N/A	1794.29	2538.61

Source: LBL, China Energy Databook; IEA, WEO; NBS, Energy Statistical Yearbook.
Unit: Mtce.

3.2.3.3 Energy accounting units and fossil fuel types

The heat value and conversion factors are essential in energy statistics. Contrary to major developed countries which set national average level of heat value based on real physical test, most of China's actual units were duplicated directly from the international value during the eighties of last century and most of them are not tested physically in China (Chen, 2010).

In terms of types of fossil fuels, there is a general lack of detailed fossil fuels consumption statistics in China. The division on energy types in China still differs from the international standard. According to Appendix I, many types of fossil fuels that are accounted by international standard are still missing in China's official and publicly accessible energy data. In addition, comparing to the Energy Balance Sheet of OECD countries, China's EBS excludes new energies and secondary energy reuse despite that new and renewable energy consumption is available from *New and Renewable Energy Statistic Yearbook*. Finally, data of energy use by types of equipment for each sector is not complete.

3.2.3.4 Other shortages

In general, there is a lack of manpower on energy statistics in China (Yu, 2010; Niu, 2007). At firm level, some firms do not have specific employees in charge of (energy) statistics which is usually done by keepers of depot who do not possess sufficient statistical knowledge. At county level, there is no energy statistic unit at certain counties. At town-level, the person in charge of energy statistics are sometimes also responsible for other newly added statistic categories (such as the "test of a fully xiaokang society", certain service sectors as well as other temporarily added statistical items).

At the consumption side, systematical statistical sources are available only for state-owned firms and private up-to-scale firms (counted by annual turnover up to 5 Mn Yuan). Energy consumption of small and middle size industries as well as agriculture and tertiary sectors is estimated based on surveys (Zhu, 2005). At the supply side, only the energy use flow of electricity sector is relatively sound and the system on the flow of coal and oil need to be ameliorated in general. Plus, certain energy sale or supply firms have experienced major corporate restructuring in recent years which has weakened the statistical function in such firms.

4. Instruction of GDP data used in the thesis

Despite the fact that there would be further convergence between central and local data, in this thesis, central statistic data are used given their easy accessibility. GDP calculated by production approach is used by the thesis basically for two reasons. First, as mentioned above, the data are more reliable than GDP calculated by expenditure approach. In addition, one of the major focuses of the thesis lays on industry energy consumption, production GDP is a better reference to energy consumption due to production activity.

Due to the reason of partial statistical problems of sectoral GDP data from SY mentioned above, this thesis uses sectoral data from 2007 IO table (which is the most up-to-dated IO table of China), where sectoral gross output and sectoral value-added are available.

5. Sectoral energy consumption data adjustment

One of the most frequently used data in this thesis is the sectoral energy consumption (by fuel types) in China. As shown above, some of the current statistical drawbacks cannot be easily adjusted due to data and method limits. However, one feasible adjustment can be done in order to prevent from double counting problem when using the current Chinese data of sectoral energy consumption. This part provides the method and explanation on how sectoral energy consumption data can be adjusted to a proper form for the analysis of the thesis.

5.1 Description of the original data

The SY and ESY of China provide sectoral total energy consumption at 44-sector level[30]. However, they do not distinguish final energy use and intermediate energy input. For most of the sectors, the given consumption of certain energy can be considered as final energy use, while for certain energy production sectors, for example the oil refinery and coke processing sectors, the input of raw coal and crude oil respectively, is converted into secondary energy products, such as coke and oil products. The carbon in primary energy is not converted into CO2 in such a process. The direct use of the raw coal and/or crude oil consumption data of such sectors would cause double counting problems in terms of CO2 emissions.

Before the demonstration of data adjustment, it is important to explain the structure of data provided by SY and ESY in order to understand our method for those who are not familiar with Chinese statistical reporting system. Both SY and ESY provide data of sectoral **total energy consumption** by fuel types (always at 44-sector level). However, only nine energy types are given at this 44-sector aggregation level. They are respectively, coal, coke, crude oil, gasoline, kerosene, diesel, fuel oil, natural gas and electricity. Beside, ESY also provides sectoral **final energy consumption** data with more fuel/energy types. However such data is only available for 39 industry and energy supply sectors under the same 44-sector aggregation (that is without "agriculture", "construction", "transport, storage and post", "wholesale, retail trade and hotel, restaurants" and "others" sectors).

5.2 Data adjustment

A data adjustment process is given to estimate real sectoral coal and crude oil consumption which is defined as a combustion behavior that emits CO2 into the atmosphere. However, it must be recalled that the energy consumption data given by SY includes also non-energy use. Due to data unavailability, such non-energy use cannot be separated from energy use. This thesis assumes therefore that such non-energy use can be treated as energy use by each sector.

The data adjustment is achieved as follows. The first sector treated is "processing of petroleum, coking, processing of nuclear fuel sector" (shortly for PP sector). Its total crude oil consumption in 2007 given by 2009 SY is 303.09 Mn tons (real quantity), while the total sectoral energy consumption of PP sector given by 2009 SY is merely 131.77 Mn standard coal equivalent (SCE). This indicates that the 303.09 Mn tons of crude oil consumption represents the crude oil which is inputted into the PP sector, while not all of them are really consumed by the sector in terms of CO2 emissions.

Figure three illustrates such a relation. The left block indicates the amount of crude oil used for producing oil products in China. This part will be transformed into oil products which will be used for domestic consumption and export (respectively, part

[30] Household sector is not included under the 44-sector aggregation. Related energy data for household is available at SY and ESY published each year.

A and B on the right side of figure 3). However, only the data of domestic consumption of such oil products is available by SY and ESY, which is composed by domestic and imported oil products (respectively part A and C on the right side of figure 3). Under such clear situation of data components, Equation 1 is used to obtain real crude oil consumption of PP sector (RCoil) which eliminates the amount of crude oil converted into final oil products,

$$RCoil = OR_{i,pp} - \sum_i (foci + exfoi - imfoi) \qquad (1)$$

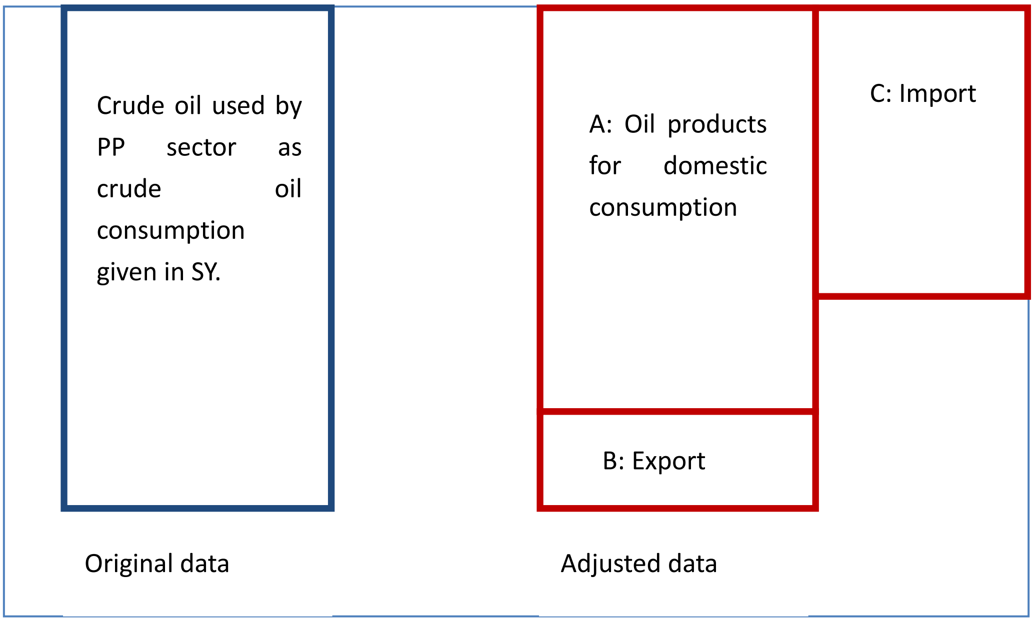
Where $OR_{i,pp}$ is the original crude oil consumption data of PP sector (303.09 Mn tons here), foci denotes the ith type of final oil product consumed at domestic. Exfoi and imfoi denotes respectively the exported and imported amount of ith type of final oil.

However, as mentioned above in Part 5.1, only the data of gasoline, kerosene, diesel and fuel oil consumption, import and export is available. A further step is used to obtain foci, exfoi and imfoi data of three additional fuels (liquefied petroleum gas (LPG), refinery gas and other oil gas). We use the end-use consumption of industrial sectors (39 sectors based on 44-sector aggregation) of these three types of oil products provided by ESY. Despite the fact that related data of end-use consumption for agricultural and service sectors is not available, this approach provides so far the most approximate estimation for separating the equivalent crude oil intermediate use for producing major oil products from crude oil consumption of PP sector. However, as the sectoral total energy consumption table of SY does not provide the latter three oil products consumption thus having no corresponding column in tables of SY, related sectoral consumption of such products is added to the item of crude oil consumption of each industrial sector, and the name of the column is also adjusted to "consumption of crude oil and LPG, refinery gas and other oil gases". This results 92.9 Mn SCE as the total real crude oil consumption of PP sector[31] instead of the original data of 303.09 Mn tons (physical quantity).

We now look at the coal consumption of PP sector. According to the same data source, the coal consumption of PP sector is 256.56 Mn ton (physic quantity) which is the quantity inputted into the sector and not really consumed by the sector in terms of energy combustion or CO2 emissions. Using total PP sectoral energy consumption (131.77 Mn tons SCE) minus all non-coal consumption of PP sector (in SCE), the real coal consumption of coal is obtained as 22.52 Mn tons SCE.

[31] Of course, as SY does not provide energy consumption data of other types of oil product that are not mentioned above, this adjustment assumes implicitly that other oil products are consumed (combusted) by PP sector.

Figure 3. Illustration of crude oil and oil products consumption data conversion



For mining and washing of coal sector (shortly for MW sector), the coal consumption given by 2009 SY is 165.17 Mn tons (physical quantity) and its total sectoral energy consumption is 71.7 Mn tons SCE. Following the same method of coal consumption of PP sector, the real coal consumption of MW sector can be obtained by using total sectoral consumption minus sectoral non-coal consumption (all measured in SCE), and this leads to 61.56 Mn tons SCE.

The coal consumption of production and supply of electric power and heat sector (shortly for electricity sector) can be obtained directly from SY and can be assumed totally combusted.

Equations 2-5 are adopted for data adjustment of coal consumption of sectors other than PP, MW and electricity generation. Equation 2 separates coal intermediate input for producing coke from total coal consumption of all sectors. We have i≠PP, MW and electricity sectors. The reason that B is not equal to C is that the coal consumption of other sectors may include also non energy use.

A = New total real coal consumption = total coal consumption – (coke consumption – coke import + coke export) (2)

B = A – real (adjusted) coal consumption of PP, MW and electricity sectors (3)

C = The sum of sectoral coal consumption of sectors other than PP, MW and electricity sectors (4)

Adjusted sectoral coal consumption of ith sector = original sectoral coal consumption of ith sector*(B/C) (5)

We therefore use the adjusted data of sectoral energy consumption by fuel types for the whole thesis.

6. CO2 emission factors

Due to data unavailability of industrial process CO2 emissions (except cement), the CO2 emissions mentioned in the thesis refer to those generated by the combustion of fossil fuels. Also, due to the lack of data, it is assumed that all fossil fuels consumption provided by ESY for a given sector is for energy use. This may overestimate the CO2 emissions for certain sectors where the non-energy use of fossil fuels is relatively high (for example, chemical and fiber sectors).

So far, there are no detailed carbon contents of fossil fuels in China database. In this thesis, carbon contents of fossil fuels are taken from the IPCC Guidelines for National Greenhouse Gas Inventories (2006). As shown above, ESY provides only sectoral total energy consumption in forms of physical amount. The converter from real physical quantity to standard coal is therefore used from China's Energy Statistics. In this thesis, one kilogram of standard coal is equivalent to 29270kJ. The combustion rate of fossil fuels is obtained from Ou et al. (2010) taken the Chinese energy context mentioned above. Table three enlists all related CO2 emission converters for the thesis.

Table 3. Carbon contents, standard coal equivalent and combustion rate

	Coal	Coke	Oil	Gasoline	Kerosene	Diesel	Fuel Oil	Natural gas
Unit physical to coal standard	0.7143	0.9714	1.4286	1.4714	1.4714	1.4571	1.4286	1.33(kgce/cu.m)
Carbon content (tC/TJ)	25.8	29.2	20	18.9	19.6	20.2	21.1	15.3
Combustion rate	0.9	0.9	0.98	0.98	0.98	0.98	0.98	0.99

Source: author's arrangement based on related data.

7. Trade data

Custom-Info database (www.customs-info.com) is the principal source of detailed export/import data of China used by the thesis. It is supervised by China's Customs Information Center which is a department of the General Administration of Customs of China. It is an online information service platform of import-export trade, providing comprehensive customs data at product level (HS-10). The monetary unit is US dollar with imports accounted by CIF (cost, insurance, weight) and exports measured by FOB (free on board) price. Beside the monetary term, Custom-Info also provides quantity of which the unit depends on specific product. However, Custom-Info only gives Chinese trade data, UNComtrade database is then used for global trade analysis. For both databases, Harmonised System (HS) is used for the classification of traded goods.

8. Conclusion

This chapter presents data source and adjustment for the use of the whole thesis. It has illustrated **two fundamental issues**. First, there is a **general improvement** in GDP and energy statistics in China in recent years, thus indicating the increasing degree of data accuracy and credibility. However, it has also shown that **several statistical drawbacks and differences** to international statistical standard still exist and a clear presentation of such discrepancies can be very useful for interpreting analytical results based on Chinese data. Second, the most detailed sectoral energy consumption data by energy types is provided by Energy Statistical Yearbook of China. However, this data does not separate intermediate and final energy consumption. This will cause double counting problems particularly for energy supply sectors (such as electricity, coking, etc.) if one uses directly the official data. Therefore, this chapter demonstrates a simple approach of **data adjustment**. So far, little studies have provided such an explicit explanation of data composition and data adjustment which can be very important for studies on sectoral energy consumption or CO_2 emissions calculation.

Although necessary efforts have been done in order to ensure data accuracy and credibility, the following drawbacks and insufficiencies which can reduce accuracy still exist due to unavailability of data or data adjustment techniques. They should be clearly kept in mind during the lecture of the whole thesis in order to understand the representativeness of results obtained from these data:

Definition of CO_2 emissions:

Except cement sector (as have mentioned in Chapter One during the SIC-GE model presentation), industrial process emissions data is unavailable so far in China. The CO2 emissions of a sector are calculated based on fossil fuels used by that sector.

Non-energy use data:

Sectoral energy consumption data contains both energy (oxidation) and non-energy (which does not generate CO_2 emissions) uses. So far, they are not given separately and we cannot separate non-energy use of fossil fuels of a sector from energy consumption data. We assume therefore that for a given sector, all fossil fuels consumption leads to CO_2 emissions. This can artificially overestimate the CO_2 emissions for certain sectors, for example, the chemical sector.

Energy types:

As Appendix I shows, IPCC provides more than fifty types of fossil fuels while current Chinese statistics only around twenty types of fossil fuels. Some are compatible in names while other types of fossil fuels provided by Chinese statistics are not really compatible with IPCC standard. This will reduce accuracy when calculating sectoral CO_2 emissions.

CO_2 emissions factor:

We have used the IPCC default data of CO_2 emission factors for fossil fuels. As have mentioned in this chapter, real CO_2 emission factors can differ for a given type of fossil fuel, for example, coal. Neither detailed CO_2 emission factors nor the consumption of fossil fuels which correspond to that factor is available in China. This reduces the accuracy of CO_2 emissions calculation.

References[32]:

Adams, F.G., Chen, Y., 1996. Skepticism about Chinese GDP growth – The Chinese GDP elasticity of energy consumption, *Journal of Economic and Social Measurement*, 22(4), pp.231-240.

Cai, Y., 2000. Between state and peasant: local cadres and statistical reporting in rural China, *China Quarterly*, 163, pp.783-805.

Central Office of the State Council of China, 2004. Guo Fa Ban (2004), No.82. (in Chinese)

Chai, J., Guo, J.E., Wang, S.Y., Lai, K.K., 2009. Why does energy intensity fluctuate in China? *Energy Policy*, 37, pp.5717-5731.

Chen, H., 2010. Discussion on influence of coal actual calorific value on energy statistics, *Coal Quality Technology*, 2010 (02), pp.48-50. (in Chinese)

Fan, Y., Liao, H., Wei, Y.M., 2007. Can market oriented economic reforms contribute to energy efficiency improvement? Evidence from China, *Energy Policy*, 35, pp.2287-2295.

Holz, C.A., 2003a. Deconstructing China's GDP statistics, China Economic Review 15, pp.164-202.

Holz, C.A., 2003b. 'Fast, clear and accurate.' How reliable are Chinese output and economic growth statistics? *China Quarterly*, 173, pp.122-163.

Holz, C.A., 2006. Revisions to China's GDP data following the 2004 economic census: more questions than answers?, available at SSRN: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=904803

Hu, Y., 2007. Implementation of voluntary agreements for energy efficiency in China, *Energy Policy*, 35, pp.5541-5548.

IEA, 2009. CO2 emissions from fuel combustion, highlights (2009 Edition), IEA, Paris. Available at http://www.iea.org/co2highlights/CO2highlights.pdf

IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 2 Energy, 2006.

Keidel, A., 2001. China's GDP expenditure accounts, *China Economic Review*, 12(4), pp.355-367.

Liao, H., Fan, Y., Wei, Y.M., 2007. What induced China's energy intensity to fluctuate: 1997-2006?, *Energy Policy*, 35, pp.4640-4649.

Liu, L.P., 1997. The reconciliation of national GDP estimates with regional ones in China, in Research of methodological issues on national accounts, Department of National Economic Accounting, State Statistical Bureau, Beijing, 1997.

Ma., H., Oxley, L., Gibson, J., 2009. Substitution possibilities and determinants of energy intensity for China, *Energy Policy*, 37, pp.1793-1804.

Maddison, A., 1998. *Chinese economic performance in the long run*, OECD, Paris.

NBS, 2003. Guo Tong Zi (2003) No.70. (in Chinese)

NBS, 2005a. Guo Tong Zi (2005), No.14. (in Chinese)

NBS, 2005b. Guo Tong Zi (2005) No.20. (in Chinese)

NBS, 2006. Notice on historical data adjustment of GDP in China, available at http://www.stats.gov.cn/tjdt/zygg/sjxdtzgg/t20060109_402370997.htm (in Chinese)

NBS, 2010a. Explanation on 2009 energy consumption of China, available at http://www.stats.gov.cn/tjdt/zygg/sjxdtzgg/t20100812_402664717.htm (in Chinese)

NBS, 2010b. Command from NBS No. 13, available at http://www.stats.gov.cn/tjdt/zygg/gjtjjgg/t20100210_402621290.htm (in Chinese)

NBS, 2010c. Command from NBS No. 14, available at http://www.stats.gov.cn/tjdt/zygg/gjtjjgg/t20100609_402648686.htm (in Chinese)

[32] Also including references cited in appendixes.

Niu, H.B., 2007. Concepts on energy consumption statistics, *Zhejiang Statistics*, 2007 (02), pp.32-33. (in Chinese)

OECD, 2000. *China in the global economy, National accounts for China, Sources and methods,* OECD, 2000, Paris.

Oster, S., Swartz, S., 2010. China disputes IEA data on energy, the Wall Street Journal, July 21, 2010. Available at http://online.wsj.com/article/SB10001424052748703720504575378243321158992.html

Ou, X.M., Zhang, X.L., Chang, S.Y., 2010. Alternative fuel buses currently in use in China: life-cycle fossil energy use, GHG emissions and policy recommendations, *Energy Policy* 38, pp.406-418.

Peng, Z.L., Liu, L.P., Zhao, T.L., Deng, W.P., Lu, Z.P., Shen, Z., Tang, Y.H., 2009. Study on Regional GDP Accounting Pattern of Four Countries, *Statistical Research*, Vol.26 (4), pp.40-43 (in Chinese).

Price, L., Sinton, J.E., Worrell, E., Phylipsen, D., Hu, X., Li, J., 2002. Energy use and carbon dioxide emissions from steel production in China, *Energy* 27, pp429-446.

Rawski, T.G., 2001a. China by the numbers: how reform has affected China's economic statistics, *China Perspective*, 33, pp.25-34.

Rawski, T.G., 2001b. What is happening to China's GDP statistics? *China Economic Review*, 12(4), pp.347-354.

Sinton, J.E., 2001. Accuracy and reliability of China's energy statistics, *China Economic Review*, 12(4), pp.373-383.

Sinton, J.E., Gridley, D.G., 2001. A guide to China's energy statistics, Lawrence Berkeley National Laboratory, available at http://china.lbl.gov/publications/guide-chinas-energy-statistics

Sinton, J.E., Gridley, D.G., 2000. What goes up: recent trends in China's energy consumption. *Energy Policy*, 28, pp.671-687.

Teng, F., Wang, Y., Gu, A., Xu, R., Mcmahon, H., Seligsohn, D., 2009. Mitigation actions in China: Measurement, reporting and verification, WRI working paper. http://pdf.wri.org/working_papers/china_mrv.pdf

Wang, X.T., 2010. China to improve GDP calculation methods, China Daily, 30/01/2010. Available at http://www2.chinadaily.com.cn/china/2010-01/30/content_9401838.htm

Wu, G.H., 2009. Nengyuan tongji yu shijie jiegui de jianyi, *Statistics and Decision* 2009 (12), pp.56-58. (in Chinese)

Xu, X.C., 2002. China's GDP accounting, *China Economic Quarterly* (Jing Ji Xue) 2002 Vol. 4, pp.23-36. (in Chinese)

Xu, X.C., 2008. Some differences in GDP measurements between China's practice and 1993 SNA guideline, *China Economic Review* 19, pp.480-488.

Xu, S., 2004. China's statistical system and resources, *Journal of Government Information*, 30, pp.87-109.

Yang, M., 2010. China's energy efficiency target 2010, *Energy Policy* 36, pp.561-570.

Yu, M.L., 2010. Xianji nengyuan tongji wenti yu jianyi, *Manager Journal*, 2010 (01), pp.348. (in Chinese)

Zhang, Z.X., 2010. Copenhagen and beyond: reflections on China's stance and responses, East-West Center Working Papers, No. 111, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1586058

Zhu, H., 2005. Meeting requests of scientific development by improving energy balance statistics, *Energy of China*, 2005 (07), pp.16-20. (in Chinese)

Appendix A. National account system

National economy can be interpreted by three levels in national account systems. First, it is the sum of all sectors of an economy, concretely primary, secondary and tertiary sectors. Second, it includes activities on physical commodities and monetary assets. Third, it is composed by four elements of social reproduction: production, allocation, exchange and consumption. Based on macroeconomic theories of balance between aggregate supply and demand, national account includes data from statistical, accounting and operation systems and aims to reflect the functioning of national economy while making no analysis. Theories, methodologies and data acquired are thus named national account system. Two major national account systems existed: Material Product System (MPS) was adopted by countries with planning economy, such as the Soviet Union, former eastern European countries and China during the last quarter of 20th century. Two versions of MPS are published in 1971 and 1984. MPS was gradually replaced by System of National Account (SNA) as countries with planning economy transited into market economy at the end of last century. The SNA was introduced after the economic crisis during the 1930s where the Keynesian began to dominate over Adam Smith. Its first version was published by the UN in 1953, followed by 1968 and 1993 versions in order to fulfill the need of changing economic structures.

Table A1 compares major differences between MPS and SNA. First, in terms of sector division, SNA is based on the theory that the wealth creating factors include capital, land, labor, which generate respectively returns of capital, rental and wage. MPS includes only the wealth created by material products, thus accounts the primary, secondary and the margin sectors in tertiary sector under SNA. Second, total economic amount is calculated based on the value-added of each sector SNA, while the total economic amount under MPS is obtained based on total product and net product. The former includes total transferred product and net product. The national total product and total revenue are calculated by summing each sector's total product and net product, respectively. Third, SNA is illustrated in forms of account (T-account for example) and the MPS is given in balance sheets.

Table A1. Comparison of SNA and MPS

	Sector	Total amount	Method
SNA	Primary, secondary and tertiary sectors	Value-added	T-account
MPS	Material product sectors only: agriculture, industry, construction, transport&post, commerce&accommodation.	Total product, net product.	Balance sheets: social total product, IO table, financial flows, balance sheet, national assets.

Appendix B. China's national account reform and current national account system in China

China's national account system reform can be divided into three steps:

Firstly, 1949-1985: MPS delayed by social movements.

The first tentative of implementing MPS was carried through the accounting of agriculture and industry sectors under the contribution of experts from Soviet Union. The account was gradually completed to all five sectors (see Appendix A) and the efforts of making related balance sheets under MPS were made, but delayed by social movements during 1960s and 1970s. The complete IO table was only done until 1981, followed by another version of 1983.

Secondly, 1985-1992: mixed system of MPS and SNA.

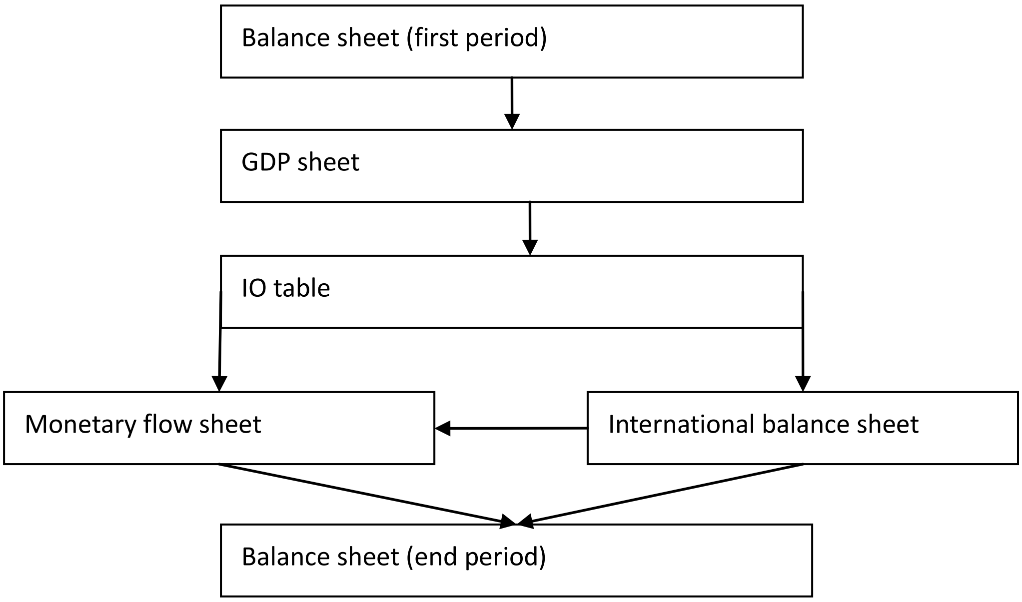
After the economic reform decision made by 1978, debates on the definition of production range related to national account have emerged, focusing on whether non-material product sectors should be included into national account. Under such increasing debates, the initiative of the transition of national account in China finally took place in 1985. Seven years after the economic reform, the material product sectors have achieved great growth while the non-material product sectors have made less growth, thus causing a biased economic structure. Therefore, the development of non-material sectors was put on the top of agenda, and the need of related statistical services on such sector which did not exist at the time emerged. In such context, the State Council established the Group of National Economy Account which made pilot programs aiming to merging MPS and SNA in China. Such mixed account system was finally implemented at national wide in 1992, following the order of the State Council.

Thirdly, 1993-now: reforms toward SNA compatible.

After the breakdown of the Soviet Union, the MPS became abandoned. Coincidentally, the UN introduced the 1993 version SNA which paved further motives for China to introduce complete SNA system. As a result, China published its international balance sheet and national economic circular account in 1995 based on SNA standard. In 2003, China published Industrial classification for national economic activities (ICNEA) (GB/T4754-2002) which symbolizes the new era of SNA compatible national account system.

Despite such voluntary transition of its national account toward total SNA approach, the current national account system in China is still conducted under mixed method of balance sheets (MPS) and account (SNA). Current balance sheet system is composed by five balance sheets. Figure B1 illustrates their relation.

Figure B1. Relations between balance sheets under current national account system



Source: author's rearrangement based on governmental information websites.

The current account system is composed by total economy account, domestic institutes account and foreign institutes account. Total economy account sums regional and sectoral economic accounts. Domestic institutes account includes non-financial firms, financial institutes, government and households. It corresponds to total economy account by setting accounts on production, allocation, expense, capital, financial assets and balance account (assets and debts). Finally, foreign institute account is composed by accounts on current account, capital, financial account and balance account (assets and debts) of foreign institutes.

Appendix C. Amelioration of Statistical standards

Unsurprisingly, several problems were encountered during China's statistical system transition, such as the lack of a complete and unique accounting approach and the ambiguous data communication process. These shortcomings have meant that aspects of GDP statistics have been called into question, such as the meaning of individual statistic variables and data reliability, while even claims of falsification were made during the late 1990s and early 2000s (for example, Cai, 2000; Rawski, 2001a, 2001b; Adams and Chen, 1996; Keidel, 2001; Holtz, 2003a, 2003b). Since 2003, due to an incompatibility between the country's statistical system and its rapid social and economic development, China has begun to reform its methods of dealing with data in order to improve the overall quality of its statistics.

As table C1 shows, China has developed a complete and generally comparable system of statistical standards. In 2002 China made a second modification to its Industrial Classification for National Economic Activities (ICNEA) (GB/T4754-2002) which improved the sectoral classification standard for use in statistical analyses. Also, on 22 January 2010, China published its Product Classification for Statistics (NBS, 2010b) based on the UN's Central Product Classification (CPC) system, which established a shared nomenclature between CPC and ICNEA. Furthermore, on 20 May 2010 the NBS released region division codes and urban and rural classification codes that were specifically intended to facilitate statistical analysis (NBS, 2010c). However, table C1 also shows that most of the improvements of GDP statistical standards were implemented in 2010, which implies that it may still require a certain time before a complete application of such standards.

Table C1. GDP statistical standards in China

Year	Name	Contents
2002	Industrial classification for national economic activities (ICNEA) (GB/T4754-2002)	Improved sectoral classification standard for statistical works
2010	Product Classification for Statistics (NBS, 2010b)	Based on UN's Central Product Classification (CPC) system, this classification sets nomenclature with CPC and ICNEA
2010	Region division codes and urban and rural classification codes	Such codes dedicated specifically to improving statistical works.

Appendix D. Transparency and comprehensibility

In general, China has ameliorated data transparency and comprehensibility. The actual Chinese statistical process demands that related data should be published to accompany the GDP data release and that calculation method should be published where necessary (NBS, 2003). Three steps for GDP accounting and data publication are requested (NBS, 2003). The initial accounting of the GDP of a certain year (noted as year t) should be published around January 20 and written into Macroeconomic Statistical Communiqué (MC) and Statistical Abstract (SA) published respectively in February and May of the following year (noted as year t+1 with regard to year t). The adjusted value of GDP is based on annual statistical data and is given in annual SY published in September of the same year (year t+1). The final value of GDP (of year t) is based on the agglomeration of annual statistical data, sectoral accountings, final fiscal accounts and surveys. It should be published respectively in the SA and annual SY in May and September in the year after (year t+2). For a reason of not to make confusions with real statistic data, China canceled the publication process of anticipated GDP in 2003 of which the release of the GDP (of year t) used to be fixed at the end of year t and calculated based on the first 11 months' data of the year (NBS, 2003). Finally, GDP and GDP growth data should be adjusted and published when national census or a change of GDP calculation method or classification have been made (NBS, 2003). However, probably for a reason of massive statistical data charges, the t year SY published in year t+1 does not always give year t's GDP. Year t's GDP is usually given in the SY published in year t+2, with a delay one more year than that is officially required.

In addition, Benchmark revisions are required following major censuses or improvements to evaluation procedures (NBS, 2003). In recent years, the data collection frequency has been increased to provide a better reflection of China's rapid economic expansion. The first large-scale benchmark revision to GDP data took place in 1995. It revised the data from 1978 to 1993 based on the results of the first Census of the tertiary sector; a census that was carried out between 1993 and 1995 and itself revised the 1991 and 1992 data[33]. This Census made up for the shortage of statistics from the service sector, a sector that expanded following economic reform in China. The second benchmark revision on historical data was carried out in 2006, where the GDP of 1993 to 2004 was revised, based on the results of the first Economic Census that set 2004 data as the base year (NBS, 2006). Results from the second modification are provided by the NBS (2006). The third benchmark revision on historical data adjustment finished in 2010 and revised the 2005 to 2008 GDP, based on the second Economic Census.

The above-mentioned GDP adjustment process can be illustrated by table D1. The initial value of 2005 GDP is 18232.1 billion yuan which is published by the 2005 MC in February 2006 (row 2005, column initial data). The adjusted 2005 GDP published by the 2006 SY in mid-2007 (row 2005, column 2006 SY) is 18308.48 billion yuan. The

[33] Details available in the *1995 Statistical Yearbook* and *Data of Gross Domestic Product of China 1952-1995.*

table shows the way in which this 2005 GDP was subsequently adjusted, for example to 18386.79 billion yuan by the 2007 SY published in mid-2008. The second economic census, completed in 2010, also made general GDP data adjustments to earlier years, as shown in the table. The most up-to-date GDP data are provided in the 2010 MC column, this data being published at the end of February 2010.

One insufficiency concerning GDP data adjustment so far is that detailed data adjustment process is not publicly available, which caused doubts for example on how specific statistical terms have been adjusted (Holz, 2006).

Table D1. Initial and adjusted data of nominal GDP 2005-2009 (100 Mn yuan)

	Initial data	**2006 SY (2007)**	**2007 SY (2008)**	**2008 SY (2009)**	**2009 SY (2010)**	**Eco Cen 2nd (2010)**	**2010 MC (2011)**
2005	182321	183084.8	183867.9	183217.4	183217.4	184937.4	
2006	209407		210871	211923.5	211923.5	216314.4	
2007	246619			249529.9	257305.6	265810.3	
2008	300670				300670	314045.4	
2009	335353						340903
2010	397983						397983

Note: the nominal GDP of 2008 was adjusted to 31404.5 bn yuan after the second economic census which has been finished in 2010. This adjustment was after the publication of 2009 SY which did not adjust the 2008 GDP.

Appendix E. Reforms on central-local statistics

China has made reforms aiming to clarify national and provincial statistic works, which are not well reconciled due to differences in data source and calculation approaches (Liu, 1997). So far, there is no complete regional accounting system in the world as a reason of the complexity of the separation of national institutions among regions. SNA only sets guideline for national-wide statistic works but does not provide systematical framework on regional GDP accounting. Regional GDP which is directly linked to local government performance assessment in China has greatly attracted local governors' attention (Peng et al., 2009) which tends to overestimate their regional GDP. Noted that provincial trimester GDP was calculated and published by province itself before 2004, the sum of both provincial GDP and provincial GDP growth rate are usually superior to national statistics, particularly in 2004 (Wang, 2010). Facing such discrepancy, several reforms have been implemented since then in order to regularize local GDP statistics. Major reforms include:

Effectuate provincial GDP joint auditing: after each trimester, NBS together with local statistic entities should effectuate general auditing on all provincial GDP data and should make corrections on errors if necessary (Central Office of the State Council of China, 2004).

Ameliorate the statistical standards on sectoral GDP: NBS should set unique and nationally comparable method on different sectors in order to unify the statistical methodology (NBS, 2005a, 2005b). Auditing system should be established based on this method in order to examine provincial statistics on key sectors.

Establish progressively down-turned statistical system: The national level GDP will be calculated by the upper administrative level and consequentially, the provincial GDP should be directly calculated by the NBS. With regard to the separate provincial trimesterial publication of data, these data will no longer be published by provincial statistic bureaus but will be centralized with the NBS after joint auditing (NBS, 2005a).

Data Auditing by experts: NBS has also established the data quality evaluation system and set up the Experts Consultation Group of National Accounts and the Leading Group of GDP Accounting Coordination in 2004 which assemble related experts to revise statistical data before releasing.

Appendix F. China's energy statistics improvement

China's energy administration has experienced sixteen reforms, eleven of which took place during the planning of the economic regime prior to 1978, and five after 1978 during economic transformation (Wu, 2009). So far, most of the statistical data on energy are collected from NBS and provincial statistic bureaus. The newly established National Energy Administration which plays a role as energy commissioner also participated to energy statistics. Energy data are given both by each year's SY and Energy Statistical Yearbook (ESY), and the latter usually gives more detailed and complete data than SY. Since 2004, ESY is published annually instead of biennually facing an increasing demand of energy data. In general, due to rising institutional support, China's energy statistics has made great improvements in recent years (Zhang, 2010). In table F1 (which can be read by the same way of table D1), the initial value of total energy consumption is given from MC published during the first quarter of each year. Adjustments can be made in later publications of SY and ESY. As table F1 shows, comparing to GDP data adjustment, no adjustment was made on total energy consumption since 2006 under normal statistical data adjustment approach (Zhang, 2010). For example, the initial value of total energy consumption of 2005 is 2.22 billion tons of standard coal. The total energy consumption of 2005 published in SY of the following years (2006-2009, row 2005 of table F1) remains the same value. In 2010, as a result of the second Economic Census (as mentioned above), the 2005-2009 data of total energy consumption are adjusted to a higher level.

Table F1. Initial and modified data of total energy consumption (100 Mn tce) (coal equivalent calculation)

	Initial data	**2006 SY (2007)**	**2007 SY (2008)**	**2008 SY (2009)**	**2009 SY (2010)**	**Eco Cen 2nd (2010)**
2005	22.2	22.23	22.47	22.47	22.47	23.6
2006	24.6		24.63	24.63	24.63	25.87
2007	26.5			26.56	26.56	28.05
2008	28.5				28.5	29.14
2009	31					30.66
2010	32.5					

Appendix G. GDP accounting approach

The calculation of GDP in China is made both by production and consumption side approaches and measured by both current and constant prices.

G.1 GDP at current price

Equations G1-G3 give the calculation method of GDP by production (GDPp), income (GDPi) and expenditure (GDPe) approach.

$$\mathrm{GDPp} = \sum_{\mathrm{i}} \mathrm{GDPp_i} = \sum_{\mathrm{i}} (\mathrm{TO_i} - \mathrm{II_i}) \qquad \text{(G1)}$$

$$\mathrm{GDPi} = \sum_{\mathrm{i}} \mathrm{GDP_i} = \sum_{\mathrm{i}} (\mathrm{R_i} + \mathrm{NT_i} + \mathrm{D_i} + \mathrm{S_i}) \qquad \text{(G2)}$$

$$\mathrm{GDPe} = \mathrm{FC} + \mathrm{CF} + \mathrm{NE} \qquad \text{(G3)}$$

where index i denotes the ith sector, TOi denotes total output, IIi denotes total intermediate inputs, Ri denotes the remuneration of employees, NTi denotes the net production tax, Di denotes the depreciation, Si denotes the operating surplus, FC denotes total final consumption, CF denotes total capital formation and NE denotes net export. Detailed explanation of sectoral accounting could be found at OECD (2000). Particularly, it may worth indicating that for industrial sectors, total output is calculated by the sum of total industry output value and the sale value of wastes and wasted materials. The statistical unit for industry sector is factory based while not product based.

G.2 Constant price GDP

Constant price GDP is used majorly in long-term model projection in this thesis. This part gives instruction of official constant price GDP calculation for reference.

The constant price is calculated based on two approaches in China (Xu, 2002): deflation approach (which includes single deflation and double deflation approaches) and extrapolation approach (which includes single extrapolation and double extrapolation approaches). The single deflation approach uses output price index to obtain constant price value-added based on the current price value-added. The double deflation approach uses respectively output price index and intermediate input price index to obtain constant price total output and intermediate input based on the current price of these two values. The single extrapolation approach uses the physical output index and multiplies with base year value-added in order to obtain constant price value-added of a given year. The double extrapolation approach uses the physical output index and physical intermediate input index and multiplies respectively the total output and intermediate input of base year in order to obtain the constant price of these two values for a certain year. The constant price GDP is then the aggregation of sectoral constant price GDP calculated with mixed approaches.

Appendix H. Structure of energy balance sheet of China

Table H1 below illustrate the structure of China's energy balance sheet published each year by NBS and Energy Administration of China. Detailed data is omitted here but can be found at each year's Energy Statistical Yearbook.

Table H1. Illustration of China's energy balance sheet

	Energy Total					
1. Total primary energy supply	**Coal equivalent calculation**	**Calorific value calculation**	**Types of fossil fuels …**	**Heat**	**Electricity**	**Other energy**
Indigenous production			…			
Hydro power			…			
Nuclear power			…			
Recovery of energy			…			
Import			…			
China airplanes&ships refueling in aboard			…			
Export			…			
Foreign airplanes&ships refueling in China			…			
Stock change			…			
2. Input (-) and output (+) of transformation			…			
Thermal power			…			
Heating supply			…			
Coal washing			…			
Coking			…			
Petroleum refinery			…			
Gas works			…			
Coke input			…			
Briquettes			…			
3. Loss			…			
4. Total Final consumption			…			
Farming, forestry, animal husbandry, fishery&water conservancy			…			
Industry			…			
Non-energy use			…			
Construction			…			

Transport, storage, postal&telecommunication services			…			
Wholesale, retail trade and catering service			…			
Residential consumption			…			
Urban			…			
Rural			…			
Other			…			
5. Statstical difference			…			
6. Total energy consumption			…			

Source: Energy Statistical Yearbook of China.

Appendix I. Energy type divisions comparison: IPCC and Chinese standard

The following table I1 compares energy types between IPCC and Chinese statistical standard. As seen, a lot of energy types are still missing in current Chinese energy statistic system. This reduces data accuracy.

Table I1. Comparison of energy types between IPCC and Chinese statistics

Solid (coal and coal products)	
IPCC OECD category	**Related energy type division of China**
Anthracite	Raw coal
Coking coal	Cleaned coal
Other Bituminous coal	Other washed coal
Sub-bituminous coal	
Lignite	
Oil Shale and Tar sands	
Brown coal briquettes	Briquettes
Patent fuel	
Coke (Coke-oven coke and lignite coke; Gas coke)	Coke; other coking products
Coal tar	
Derived gases (Gas works gas, coke-oven gas, blast-furnace gas, oxygen steel furnace gas)	Coke oven gas; other gas

Liquid (crude oil and petroleum products)	
IPCC OECD category	**China**
Crude oil	Crude oil
Orimulsion	
Natural gas liquids (NGLs)	
Gasoline (Motor, Aviation, Jet)	Gasoline
Jet kerosene	Kerosene
Other kerosene	Fuel oil
Shale oil	
Gas/diesel oil	Diesel oil
Residual fuel oil	
Liquefied petroleum gases	LPG
Ethane	
Naphtha	
Bitumen	
Lubricants	
Petroleum coke	
Refinery feedstocks	
Other oil (refinery gas, waxes, white spirit & SBP, other petroleum products)	Refinery gas; other petroleum products

Gas (natural gas)	
IPCC OECD category	**China**
Natural gas	Natural gas

Other fossil fuels	
IPCC OECD category	**China**
Municipal wastes (non-biomass fraction)	
Industrial wastes	
Waste oils	
Peat	

Biomass	
IPCC OECD category	**China**
Solid biofuels (wood/wood waste; sulphite lyes (black liquor); other primary solid biomass; charcoal)	Separate statistics from Ministry of Agriculture on non commercial energy consumption for rural residential on biogas, stalks and firewood.
Liquid biofuels (biogasoline; biodiesels; other liquid biofuels)	
Gas biomass (landfill gas, sludge gas, other biogas)	
Other non-fossil fuels (municipal wastes (biomass fraction))	

Source: author's arrangement based on IPCC (2006) and Energy Statistical Yearbook of China.

Chapter Three. Impacts of domestic carbon price in China[34]

1. Introduction

Market-based instruments which offer a level of cost-effectiveness have recently drawn the attention of the Chinese government. However, **thus far there are no systematic and explicit fiscal measures dedicated to energy saving and CO_2 emissions reduction in China**. The taxes that exist cover only a part of China's energy mix and pollution[35]. For example, fees (charges) are imposed on 113 pollutant types including waste-water, solids, noise pollution and radioactive materials accounting for 0.4% and 0.067% of China's 2007 total taxation revenue and GDP respectively (Ministry of Environmental Protection of China). However, no fees are collected on carbon emissions. Resource taxes have been levied on coal, oil and natural gas (Liu, 2007), the revenue from which reached 26.1 billion yuan in 2007, accounting for 0.6% of the total tax revenue in that year (Ministry of Finance of China). Finally, as will be demonstrated later in this thesis, restrictive fiscal measures on exports (export tax, export VAT refund rebate, etc.), which are revised annually, have only been imposed on certain energy-intensive products, accounting for just a small share of total Chinese exports and GDP. However, despite the fact that such taxes help to reduce CO_2 emissions indirectly, they do not explicitly reflect the external carbon costs of different fossil fuels. In such context, a carbon tax and/or an emissions trading system (ETS) could give clear price signals on carbon cost (Baumol and Oats, 1998; Stern, 2009) and cover most of the CO_2 emission sources. It could not only strengthen China's efforts to develop a low carbon economy, but also provide an unmistakable signal to the international community regarding China's efforts in the fight against climate change, compared to other actions that have received limited international recognition (Zhang, 2010).

Most of the recent studies providing suggestions to policy decision of implementing carbon price in China have focused on the impact of a carbon price in terms of China's economy, the mid- and long-term incentive effects and CO_2 emissions, for example: Su (2009) and Fan et al. (2009) studied the general impact of a carbon tax on China's CO_2 emissions and GDP growth, but did not analyze impacts on a sectoral level; Liang et al. (2007) examined five major energy-intensive sectors and looked at the impact of a carbon tax on their output, prices and emissions, along with proposed exemption and subsidy measures to alleviate the negative impacts on these sectors; Jiang et al. (2009) also calculated the impact of a carbon tax on sectoral output, with projections until 2050; Brenner et al. (2007) examined the distributional effect of a carbon charge on fossil fuels in China by distinguishing

[34] This chapter contains two papers:
Wang, X., Li, J.F., Zhang, Y.X., 2011, An analysis on the short-term sectoral competitiveness impact of carbon tax in China, ***Energy Policy***, 39, pp.4144-4152.
Li, J.F., Wang, X., Zhang, Y.X. A CGE approach for analyzing carbon pricing policy in China, to be submitted soon.
[35] These indirect carbon taxes will be demonstrated in details in the following chapter.

China's rural and urban expenditure patterns, they concluded that a carbon charge with revenue recycling on an equal per capita basis could lessen the rate of increase in energy consumption and reduce income inequality; and Li (2003) adopted an econometric model projecting China's energy use under a carbon tax of 36.7 dollar/t CO_2 and concluded that it could contribute effectively to reducing energy consumption by 2030.

However, besides the importance of long-term effect for policy making, **fewer studies focused on the short-term impacts of carbon price** when analyzed entirely at the sectoral level, particularly in relation to energy-intensive sectors. Not surprisingly, carbon pricing policies deliver a direct impact to industries by increasing their marginal production costs which could weaken their competitiveness. However, as mentioned in previous chapters, even in Europe where the policy is to balance economic growth and environmental pollution, competitiveness concerns prevailed after the implementation of European Union Emission Trading Scheme (EU ETS). EU domestic industries have continuously required compensatory measures in order to protect their competitiveness (Kuik and Hofkes, 2010; Monjon and Quirion, 2010; Zhang, 2010). Given that China is still a developing country and the Chinese priority favors economic development, a politically feasible carbon price policy must balance economic development and its effect on carbon emissions. Therefore, a detailed study on short-term impact will demonstrate different degrees of carbon price impact to each sector and provides a solid basis for whether certain compensatory measures could be given to highly impacted sectors. The short-term analysis is complementary to the long-term impact analysis and consolidates the political opinion of a feasible carbon price policy.

This chapter examines both short- and long-term carbon price impacts in order to provide a scientific basis for policy making. It is organized as follows: Part Two presents the method, data and results of a static analysis of the short-term carbon price impacts at sectoral level in China; Part Three introduces an assessment on the short- and long-term impacts of carbon price under different revenue redistribution scenarios by using the SIC-GE model; Part Four concludes.

2. Static analysis of competitiveness impact of carbon price

2.1 Methods

2.1.1 Assumption

In accordance with recent carbon tax implementation proposals in China (Su, 2009), a carbon cost is assumed to apply to the production side. For simplicity, we assume that imported goods (except fossil fuels) do not pay such carbon costs and that exported goods do not receive a carbon cost refund. In China, the prices of oil and natural gas are still regulated and only the coal market is liberalized (Wang, 2007). In consequence, predicting a carbon cost price impact on fossil fuels other than coal becomes more difficult due to the influence of the government-controlled mechanism. However, it can be assumed that the incremental carbon price (cost) is wholly passed on to downstream industries as a result of governmental authorization[36]. Finally, we assume that there is no technology improvement over the short term.

2.1.2 Immediate cost increases for industries

2.1.2.1 Sectoral CO2 emissions

Direct (DCO_{2i}) and indirect (ICO_{2i}) CO_2 emissions from industrial production processes are calculated by equations 1-3. E_{ij} denotes the jth energy consumption of sector i, C_j is the carbon content of jth energy and rb_j denotes its combustion rate. Ele_i is the electricity consumption of sector i, and C denotes the units of carbon emissions from electricity in China. El_k represents the electricity generated by the consumption of the kth type of fossil fuel, EC_k and Erb_k denote respectively the carbon content of the kth fuel and its combustion rate. TEI is the total electricity (both thermal and non-thermal electricity) generated during a given year[37].

$$DCO_{2i} = \sum_j E_{ij} \times C_j \times rb_j \qquad (1)$$

$$ICO_{2i} = Ele_i \times C \qquad (2)$$

$$C = (\sum_k El_k \times EC_k \times Erb_k) / TEl \qquad (3)$$

2.1.2.2 Impact on sectoral competitiveness

Equations 4-6 establish the total analysis framework of the static approach (Hourcade et al., 2007) for assessing the impact of carbon pricing on sectoral competitiveness in China. t denotes the carbon price level, CtV_i represents the incremental carbon cost relative to sectoral value-added, VA_i. TI_i is the sectoral trade intensity in an open economy. Im_i indicates the ith sector's imports, Ex_i is the ith sector's exports and Y_i denotes the total output (turnover) of sector i.

Generally speaking, the higher the CtV, the larger the impact of the carbon cost on that sector; the higher the GDPS, the bigger the effect of a carbon cost on total GDP. The rate of trade intensity provides a first indication of a sector's level of exposure to the world economy. A higher rate indicates a higher level of a sector's exposure to the world exchange.

$$\mathrm{CtV_i} = \frac{\mathrm{t(DCO_{2,i} + ICO_{2,i})}}{\mathrm{VA_i}} \qquad (4)$$

$$\mathrm{GDPS_i} = \frac{\mathrm{VA_i}}{\mathrm{GDP}} \qquad (5)$$

[36] This assumption is only valid for Part 2.

[37] Constrained by the unavailability of data on the exact amounts and specific usages of electricity for any given sector in China, we made the assumption that the electricity consumed by each sector has the same composition of electricity generated by different sources (thermal power, hydro, etc.) and thus represents an average value.

$$\mathrm{TI_i} = \frac{\mathrm{Ex_i+Im_i}}{\mathrm{Y_i+Ex_i+Im_i}} \qquad (6)$$

2.1.2.3 Separated export and import intensity

For the Chinese situation, we have also described the potential impacts of carbon price on both the exports and imports of a sector, through the use of the terms import intensity (*IMI_i*) and export intensity (*EXI_i*), which can be obtained by equations (7) and (8):

$$\mathrm{IMI_i} = \mathrm{Im_i}/(\mathrm{Y_i} - \mathrm{Ex_i} + \mathrm{Im_i}) \qquad (7)$$
$$\mathrm{EXI_i} = \mathrm{Ex_i}/(\mathrm{Y_i} - \mathrm{Ex_i} + \mathrm{Im_i}) \qquad (8)$$

where Im_i indicates the ith sector's import, Ex_i the ith sector's export and Y_i the total output (turnover) of sector i.

Import intensity provides a measure of the domestic market share of foreign products. A high rate could be an indication of a high degree of market openness and a severe level of competition. The impact on the competitiveness of a carbon price may be more significant on sectors with higher IMI than sectors with lower IMI. IMI level can also be used as a measure of a sector's dependency on foreign products, in the case where an industry has little domestic competition. In these instances, the effect of a carbon tax on competitiveness becomes almost neutral.

The export intensity provides a measure of the rate of exported goods to domestically supplied (consumed) goods in a given sector. This figure was used to examine sectoral distribution between domestic and international markets. The higher the rate, the higher is the export dependency of that sector. A carbon price could have a greater impact on sectors with higher EXI compared to those with lower EXI through its affect on international market performance.

2.1.3 Short discussion on the methodology

It should be noted that a sector's carbon intensity is at the core of the determination of its competitiveness. Through the separation of the impacts on domestic and international market competitiveness, it provides differentiation for further compensatory measures. For example, export refunding measures could be adopted for sectors that are negatively affected in terms of their export competitiveness, while other measures could be implemented for sectors that compete mainly at the domestic level.

The reason of the different forms of denominators between equation 6 and 7-8 is that, for equation 6, the objective is to provide an assessment which can be very comparable to results obtained by using Hourcate et al. (2007) and EU Commission official methods for determining sectoral carbon leakage impact; for equations 7-8, we consider that the denominator reflects generally the gross value "remained" at domestic which might be a better base to compare with traded gross value. Still, both forms would lead to the same conclusions when analyzing trade competitiveness.

Finally, it should be stated that we used total output instead of GDP when measuring TI, IMI and EXI in order to maintain the gross value. However, gross value may not be the ideal variable for measuring competition since domestic value may be embedded in imports, while exports may include foreign value. A better measurement could be the use of value-added in domestic and foreign industries to reflect their competitiveness and how a carbon tax may affect it. Koopman et al. (2008) provide a method to extract the value-added from Chinese exports by distinguishing processing trade and normal trade. However, it remains difficult to calculate the value-added for goods imported to China since this would require each imported product to be distinguished according to its country of origin.

2.2 Data

2.2.1 Sector classification and economic data

This section use the 44 sectors integration listed by the Energy Statistical Yearbook (ESY), for reasons of simplicity and data availability constraint. Furthermore, we regroup the 44 sectors into 36 sectors for the analysis of Part 2 of this chapter. Detailed explanation of the division of sectors, data sources as well as the statistical compatibility of data from different sources is provided in Appendix A.

2.2.2 Sectoral fossil fuel consumption

We use the adjusted data of fossil fuel consumption per sector in 2007 demonstrated in Chapter Two. The carbon contents and combustion rates of fossil fuels were obtained respectively from the IPCC (2006) and Ou et al. (2009) which are also shown in Chapter Two.

2.2.3 Choice of carbon prices

To demonstrate the impact of different levels of a carbon tax on the degree of competitiveness, two carbon costs are selected, respectively 100 yuan/t CO_2 (named A1) and 10 yuan/t CO_2 (A2) for the static analysis. Approximately, the high and low rates are equal to 12 and 1 euro/t CO_2 respectively, calculated using a nominal exchange rate. For the high carbon cost, this figure could be higher and considered as a comparable carbon price to the EU ETS (for the high rate), if calculated using the PPP approach. **The low carbon cost reflects the consensus reached so far by current research proposals for implementing a carbon tax in China** (Su, 2009).

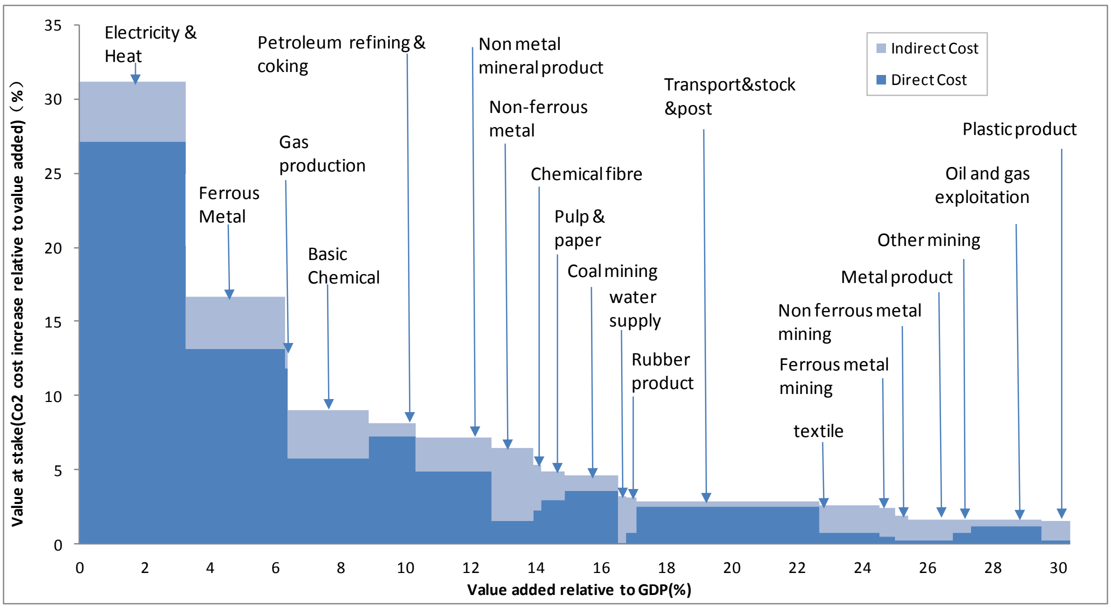
2.3 Results

2.3.1 General view

From our results we selected 20 sectors out of the total 36 that were the most affected by the CP according to their ratios of incremental carbon costs to sector value-added (CtV). As shown in figure one, with a carbon cost of 100 yuan/t CO_2, CtV levels across the different sectors can be approximately divided into three categories: high, medium and low. Electricity, heat production and supply, ferrous metal, gas production and supply sectors have the highest CtV. The medium category, which comprises eight sectors, all have CtV levels that are much lower than the high group, while the remaining sectors have low CtV levels. Similar results were found under the A2 scenarios, which can be obtained by replacing the A1 vertical axis units with 0.5, 1, 1.5, etc.

The CtV value implicitly reflects the carbon GDP intensity of each sector. The value can be obtained by dividing the CtV by the carbon tax unit rate. Further considerations regarding calculations of sector carbon intensity with related results can be found in Appendix B.

Figure 1. Impact of carbon tax on value-added at 100 yuan/t CO_2



Source: author's calculation based on related resources.

2.3.2 Energy supply sectors

The results suggest that of all the sectors analyzed, the electricity and heat supply sectors are likely to be the most affected industrial activities due to their high reliance on fossil fuels. The CtV for these activities was more than 30% in scenario A1[38]. However, as previously mentioned, it is assumed that the CtV increase due to carbon price for the electricity generation sector would be totally passed on to downstream producers, thus the incremental carbon cost would not be a burden to the sector itself. Furthermore, the electricity and heat markets in China can be considered as a state monopoly, with most of the electricity and heat being self-supplied with little foreign input (Ngan, 2010). The competitiveness impact of a carbon price in this sector would be slight given the absence of foreign competitors (imports). The same reasoning applies to the gas production and supply sector, for

[38] Values of CtV under A2 could be obtained by dividing related values in A1 by 10.

which the incremental carbon price should again be passed on wholly to downstream producers.

The next section examines the cost impact of carbon tax on the remaining manufacturing sectors under our initial assumption of a total cost pass through in energy supply industries. However, the quantified results of the electricity, heat and gas production and supply sectors remain present in the figures to demonstrate clearly the sectoral fossil fuel carbon intensity.

2.3.3 Manufacturing sectors

Among all the manufacturing sectors, the ferrous metal production sector potentially becomes the most affected sector following the implementation of a carbon price. Its CtV is 16.7% under the A1 scenario. This implies high fossil fuel intensity, particularly the high coal dependency of China's ferrous metal production sector. The CtV level is significantly lower for the other sectors. Generally, this means that these sectors are implicitly much less carbon intensive than the ferrous metal sector. The CtV value of the basic chemical sector is almost half that of the ferrous metal sector with 9.1% under A1. The CtV escalates moderately from the petrol refining and coking sector to the coal mining sector, while the CtVs of the other sectors remain relatively close to each other under all three scenarios.

To define the scale effect of the impact on competitiveness in terms of GDP, a CtV value at 1.5% above that which a carbon price may be deemed to potentially affect a sector's competitiveness is arbitrarily chosen. Under scenario A1, 20 sectors are included, the sum of their sectoral value-added accounting for 27.1% of the total Chinese GDP. Our calculations showed that three sectors had a sector value-added per total GDP (VtG) of more than 3% (including the electricity and heat sector); three sectors had a VtG of between 2 and 3%; and five sectors had a VtG of between 1 and 2%. VtG values for the remaining sectors were below 1%. Under scenario A2, only the ferrous metal sector, representing 3% of the total Chinese GDP, could be considered to be vulnerable.

2.3.4 Trade intensity and domestic market competitiveness

2.3.4.1 Results using same calculation of the EU Commission

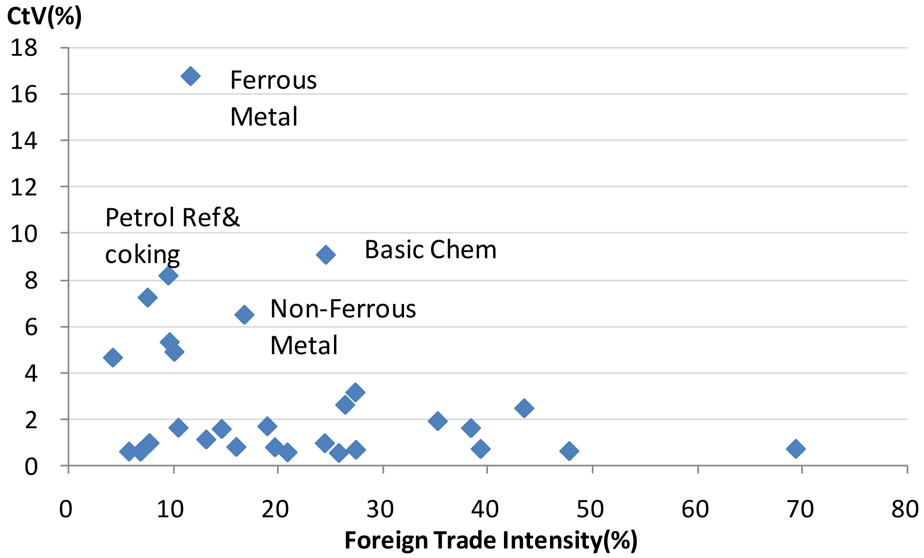
Comparing the trade intensity and cost ratios of different sectors, figure two shows that the impact on competitiveness for most sectors is relatively low at 100 yuan/tCO_2. However, several sectors could be extremely threatened by such a high carbon cost. For example, the ferrous metal, basic chemical metal and non-ferrous metal sectors have trade intensities higher than 10% and CtVs higher than 6%. If sector competitiveness is measured according to the threshold set out by the European Commission, then a sector may be deemed to be affected by a carbon policy if:

1) CtV is higher than 5% and trade intensity higher than 10%, or

2) CtV is higher than 30%, or
3) trade intensity is higher than 30%

Under this definition, the competitiveness of nine sectors, representing 13% of total Chinese GDP and 36.9% of total Chinese export (gross value), would be affected under 100yuan/tCO2.

Figure 2 Trade intensity and domestic market competitiveness (100yuan/tCO2)

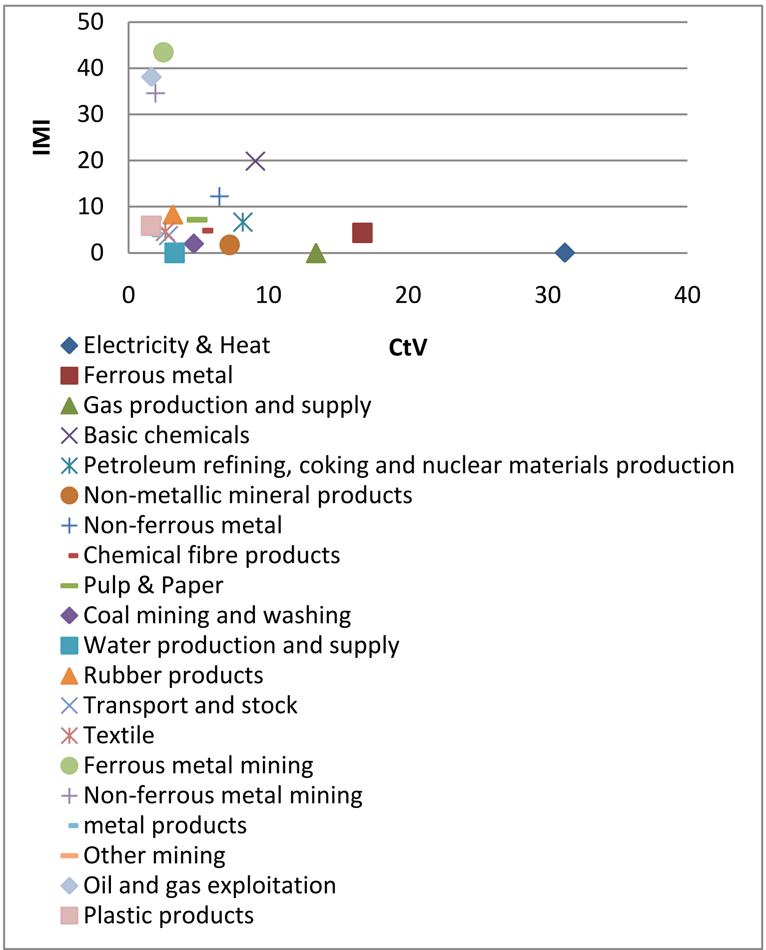


Source: author's calculation based on related resources.
Note: the results from scenario A2 (10yuan/tCO2) can be obtained simply by dividing the units of the vertical axis by 10.

2.3.4.2 Import intensity and domestic market competitiveness

To include the maximum number of sectors that a carbon price could potentially affect, we studied the import intensities of sectors with a CtV above 1.5% under scenario A1 (see Figure two). The further a sector is from the zero point in figure three, the higher the potential that the sector's domestic competitiveness as regards foreign products is affected. In general, sectors with import intensities of greater than 10% that a carbon price could potentially affect account for 6.9% of the total Chinese GDP under scenario A1. We can replace the unit of horizontal axis of figure ghree by 1, 2, 3, etc. in order to obtain A2. Under a CtV threshold of 1.5% and import intensities of greater than 10%, only electricity and ferrous metal sectors would remain affected under scenario A2. For both scenarios, sectors with a CtV that is inferior to 1.5% are assumed unaffected by carbon price, regardless of their import intensity.

Figure 3. Import intensities of potentially affected sectors under scenario A1.



Source: author's calculation based on related resources.

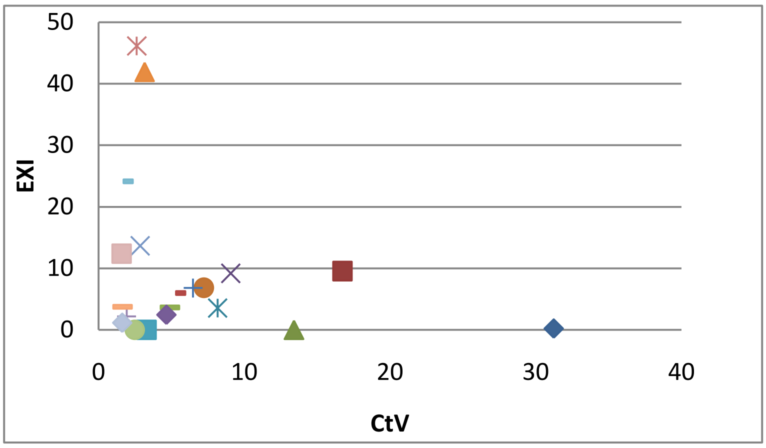
It is necessary to differentiate between the characteristics of each sector in order to examine the import intensity effect. As shown in figure three, the sectors with the highest import intensity rates are mainly composed of activities involving raw materials, including metal mining, oil and gas exploitation and basic chemicals. For the metal mining sectors (both ferrous metal mining and non-ferrous metal mining), some mining product imports (ores, for example) are conducted through contracts signed between Chinese domestic purchasers and foreign suppliers, of which the price and quantity provisions are predetermined for a given period that is usually longer than a year. The world supply capacity of such raw materials is limited and the short-term identification of new suppliers is difficult. In consequence, the possibility of an impact on short-term import intensity is low, even if the carbon cost effect is significant regarding the price difference between domestic and imported products. For oil and gas exploitation sectors, as the products are fossil fuels which could be directly affected by a carbon price through the import process, there will be no carbon cost difference in price and thus no substitution effect between domestic and imported products. For the basic chemical sector, its high import intensity may potentially lead to a substitution effect between domestic and imported products. The higher the carbon price is, the stronger the effect will be. Therefore, the domestic sector per se may be affected by increasing imports in the short term. The same conclusions can be drawn regarding the non-ferrous metal sector. However, it is worth noting that some of the products from these two sectors are frequently used to produce other goods with much higher value-added. Further studies could focus on the ratio of incremental carbon cost to final product value-added. The lower the ratio, the higher the chance that the carbon cost difference between the domestic and imported materials of such sectors would be negligible to downstream producers in the short term. Therefore, the impact on domestic competitiveness could remain ambiguous even under a high carbon price scenario.

2.3.4.3 Export intensity and international competitiveness

Similarly to section 2.3.4.2, we set a threshold of 1.5% CtV and an export intensity (EXI) of 10%, above which a sectors' international competitiveness was likely to be affected. Figure four presents the results under scenario A1, with the aim of including the maximum number of sectors that could be affected. As figure four shows, major energy-intensive sectors such as metal, chemical, pulp and paper, etc. have lower export intensities than other industries. This explains the domestic consumption-driven effect of energy-intensive products in China. In general, if we maintain the threshold levels of CtV and export intensity at 5% and 10% respectively, four sectors, which account for 10% of the total Chinese GDP, may require further examination regarding the impact of a carbon tax on their international competitiveness.

By replacing the unit of horizontal axis of 10, 20, 30, etc. in figure four by 1, 2, 3, etc., we could obtain the export intensity figures under scenario A2. Under the same 1.5% CtV and 10% EXI threshold for all three scenarios, only the electricity and ferrous metal sectors remain affected in scenario A2. The sectors with a CtV of less than 1.5% are assumed unaffected by a carbon price, regardless of their export intensities.

Figure 4. Export intensity of potentially affected sectors under scenario A1



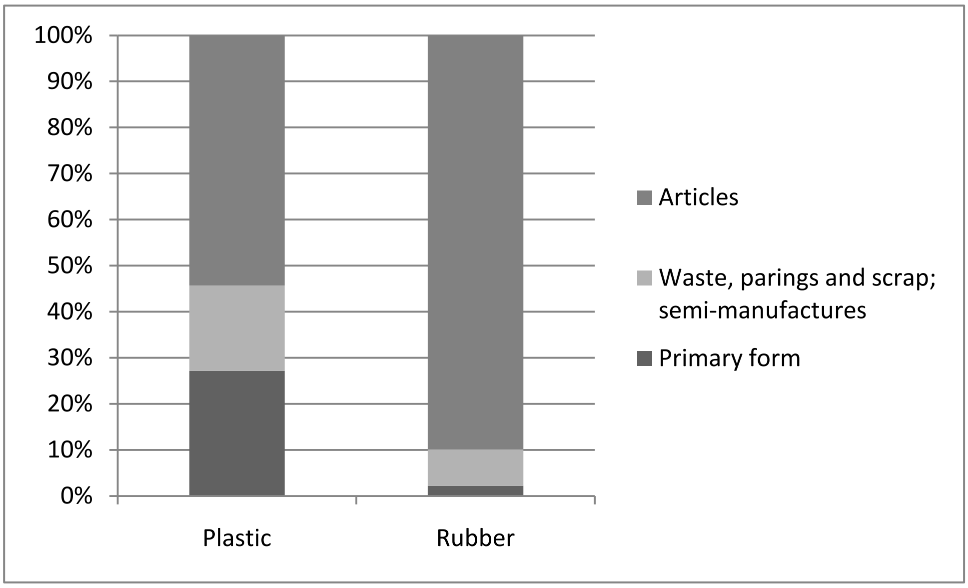
Source: author's calculation based on related resources.

The textile sector possesses the highest export intensity of all the energy-intensive sectors and, if we maintain the threshold level of export intensity at 10%, the next highest sectors are rubber, metal products, transport and stock, and plastic. Given the near homogeneity of the energy-intensity embedded into products in the textile and metal product sectors, in general their export competitiveness will potentially be affected by a carbon price at the sector level. Assessing the impact on the transport and stock sector's export competitiveness depends on further data on its fossil fuel component.

We also focused on measuring the impact of the plastic and rubber sectors' export competitiveness by distinguishing different product types at export level. Figure five shows that the main type of exported goods is final products which usually have higher value-added and lower carbon intensities than primary products. The carbon incremental cost may account for a smaller proportion of the total value-added of final products in comparison to the primary or intermediary products of these sectors. Therefore, the export competitiveness impact on the final products could be less significant than on the primary products and the total sector competitiveness impact may be reduced.

Further studies on the price rigidity of certain products in these sectors should be made in case that China is a price maker for these exported products. The incremental carbon cost will therefore have little impact on the export competitiveness of such products.

Figure 5. Share of exported products (in quantity) of plastic and rubber sectors at HS 4-digit in 2007.



Source: Custom-Info database.

2.4 Comparison with similar studies

There are both comparability and incomparability between our results and similar studies which examined the impact of carbon price on UK, German, US as well as

Japanese economies (Grubb et al., 2009; Grubb, 2009; Hourcade et al., 2007). For the former, **the sectoral statistical division method used in this paper can be considered comparable to NACE or SIC system** on which studies using the method of Hourcade et al. (2007) are based. And the sectoral value-added may also be considered closely comparable (See Appendix A for details) to value-added obtained under UN SNA system. However, for incomparability, **the major inconvenience comes from the lack of sectoral and sub-sectoral energy and CO2 emissions statistical data in China**. As shown, the sectoral CO2 emissions are not observed and are only estimated based on adjusted sectoral total energy consumption data. And the CO2 emissions of sub-sectors cannot be estimated by our approach given energy consumption data unavailability[39]. In addition, the **industrial process emissions are missing** from our analysis due to data unavailability.

2.5 Choice of threshold

The advantage of the threshold method applied here is that it allows an immediate assessment and rapid identification of sectors that would be vulnerable in the short term following the implementation of a carbon tax. However, our choice of the threshold levels (CtV, import and export intensity) to measure competitiveness impacts was arbitrary. Moreover, the threshold level does not necessarily have to be the same for all sectors. We have therefore provided related data in Table B1 of the appendix B to assist the public policy making. To highlight one example of the changes that can be initiated by a different threshold, if the CtV threshold was increased to 5%, this would lead to nine sectors accounting for 11% of total Chinese GDP that could be considered as being potentially vulnerable to a carbon tax under scenarios A1. Neither sector would be at stake under scenario A2. In the case of import intensity, if thresholds of 5% and 30% respectively were set for CtV and import intensity, above which a sector may be considered susceptible to carbon tax implementation in China, then only basic chemical and non-ferrous metal sectors, which account for 3.9% of the total Chinese GDP, would be affected under scenario A1. No sectors would be implicated under scenarios A2. A similar threshold combination applied to export intensity would not put the sector export competitiveness at risk in both two scenarios.

3. Dynamic impact of carbon price using SIC-GE model

3.1 Method

3.1.1 Calculation of carbon price

We use the approach to firstly convert the unit carbon price impact to ad valorem tax, and then to use the SIC-GE to simulate the shock on the ad valorem tax of energy, in order to have a direct comparison with the static approach presented above.

For clarity, it should be remembered that for each industry, the additional carbon cost is only added on the primary energy intermediate input and the imported

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[39] This is the case for almost all sub-sectors, however, as will be shown, for certain product, for example, cement and crude steel, the CO2 emissions per product are available from estimation of some studies.

secondary fossil fuel intermediate input of each sector. Given that the SIC-GE's IO table only includes two types of primary energy (first, coal and products; and second, oil and natural gas and products), the following system is adopted to account for a sector's direct fossil fuels consumption in a more detailed manner. Equations 9-12 set the framework for converting unique carbon cost into ad valorem taxes imposed on primary energy. The index "i" denotes the ith sector, the index "j" denotes the jth fossil fuel type included in the IO table of the SIC-GE model, the index "m" denotes the mth fossil fuel type provided by the Energy Statistical Yearbook of China (ESY) and the index "H" denotes the household sector. Here, i = 1-44[40],. Respectively,

- t_i^j denotes the ad valorem tax rate of the jth energy for the ith sector,
- t_H^j denotes the ad valorem tax rate of the jth energy for the household sector,
- t denotes the unique carbon cost, DC_{ij} denotes the direct CO2 emissions due to the consumption of the jth energy of sector i,
- DC_{ij} denotes the CO2 emissions generated by the jth type of energy of the ith sector,
- DC_{Hj} denotes the CO2 emissions generated by the jth type of energy of the household sector,
- V_{ij}^E denotes the value of the intermediary input of the jth energy into the ith sector (in monetary form),
- V_{Hj}^E denotes the value of household consumption of the jth energy. Both V_{Hj}^E and V_{ij}^E could be obtained from the non-competitive IO table of China.
- E_{xm} denotes the mth energy consumption of the xth sector (x = i and H)
- C_m denotes the mth energy carbon content (same as C_j of equation 1)
- rb_m denotes the mth energy combustion rate (same as rb_j of equation 1)

For equations 9-10, it is given that m= coal when j=coal; and m= crude oil, natural gas when j= oil and natural gas. Such arrangement is due to the fact that SIC-GE model uses two types of primary fossil fuels (represented by "j"). We therefore calculate the direct CO2 emissions from crude oil and natural gas separately and sum up for "oil and natural gas" which is given in one category of primary fossil fuels in SIC-GE.

$$t_i^j = t * DC_{ij} / V_{ij}^E \qquad (9)$$

[40] The division of the sector into 44 industry sectors is principally due to the fact that only detailed energy consumption data of the mth type of energy are available at this sectoral level. Details of the 44 sector divisions can be consulted at ESY.

$$t_H^j = t * DC_{Hj} / V_{Hj}^E \qquad (10)$$

$$DC_{ij} = \sum_m E_{im} C_m rb_m \qquad (11)$$

$$DC_{Hj} = \sum_m E_{Hm} C_m rb_m \qquad (12)$$

When converting the unique carbon cost into ad valorem tax rate of imported petroleum products, we had to apply an average ad valorem tax rate of petroleum products (t^{petrol} here) across industries due to data limitations (equation 13). Respectively,

- t^{petrol} denotes the average ad valorem carbon tax for imported secondary energy,
- DC_k^{im} denotes the CO2 emissions generated by the kth imported secondary energy, in this instance gasoline, kerosene, diesel oil and fuel oil, calculated using the same value of carbon contents and combustion rate (respectively C and rb in previous equations)
- $V_{i,petrol}^{im}$ denotes the imported amount (in monetary terms) of petrol refinery products in sector i. $V_{i,petrol}^{im}$ can also be obtained from the non-competitive IO table of China.

$$t^{petrol} = t \times \left(\sum_k DC_k^{im}\right) / \left(\sum_i V_{i,petrol}^{im}\right) \qquad (13)$$

3.1.2 Integration of carbon price into SIC-GE model

Here we assume that the increase of ad valorem tax rates and transport margin from imposing carbon price are fixed. Therefore, the shock can be made directly on the sales tax rates and margin for energy intermediate inputs for all industries and final consumptions. In SIC-GE, the purchaser price of product i involve three parts, producer price, sales tax and margins, as shown in equation (14). Transferring the variables in eqution (14) into the form rate of change in percentage, shown as lowercase ($t = \frac{\Delta T}{T} * 100$) in equation (15), is in accordance with the equation mechanism in SIC-GE model.

where, for a given ith sector

- $P_{pur,I}$ (higher case) denotes the purchaser price of the product,
- $P_{base,i}$ (higher case) denotes the base price (producer price) of the product,
- Ti denotes the sales tax (such as VAT, consumption tax, etc.),

- $Margin_i$ denotes the charge of transport and trading fee,
- $p_{pur,I}$ (in lower case) denotes the change of the purchaser price
- $p_{base,i}$ (in lower case) denotes the change of the base price
- p_i denotes the change of Pi=(1+Ti), known as the power in CGE terms
- mar_i denotes the change of the margin
- S_i^{mar} denotes the share of the margin on the purchaser's price

$$P_{pur,i} = P_{base,i}(1 + T_i)(1 + Margin_i) \qquad (14)$$
$$p_{pur,i} = (1 - S_i^{mar})(p_{base,i} + p_i) + S_i^{mar} * mar_i \qquad (15)$$

3.2 Data

Related data sources can be found in Chapter Two.

3.3 Baseline assumption and scenarios

The baseline scenario (named S0) is given for the period of 2007 based on Mai (2006). The SIC-GE model is recalibrated using *China's External Trade Indices* for the period of 2003-2008 published by the General Administration of Customs of China. Major macroeconomic variables of 2007 under S0 are given in table one.

Table 1. Major macroeconomic variables under baseline scenario (%)

	2007	2008	2009	2010	2011-2015
GDP growth (1)	14.2	9.5	9.2	10.3	9.0
Consumption growth	10.6	8.8	10.8	5.5	9.4
Capital formation growth	13.9	10.6	28.7	11.4	9.9
Export growth	19.9	8.4	-19.4	16.7	8.4
Import growth	15.8	7.7	-10	15.6	8.5
CPI growth	4.4	5.9	-0.7	2.2	2.9
Employment growth	0.8	0.6	0.6	0.6	0.6

Note: (1) Growth rate is given under constant price

We assess five policy scenarios which can be divided by two groups. Firstly, the revenue of the carbon price is not redistributed specifically and used as an increase of general government budget. Under this assumption we have three policy scenarios which take account the current electricity market price regulation in China:

S1). Free carbon cost pass through of electricity sector

S2). 50% electricity carbon cost pass through of electricity sector

S3). No carbon cost pass through of electricity sector

Secondly, the revenue of carbon price is redistributed for specific purpose. Under this assumption, we provide two scenarios where carbon cost of electricity sector is freely passed through as an assumption of governmental authorization:

S4). The revenue is redistributed to reduce production tax for enterprises

S5). The revenue is redistributed to reduce the consumption price to stimulate consumption. This scenario is based on the central objective for the 12th Five Year Plan (2011-2015) of China which aims to promote consumption-driven GDP growth.

3.4 Results

3.4.1 Impact variation

As mentioned above, the carbon cost is introduced by the shock on the ad valorem tax rate of intermediate input and the household consumption of primary energy product. The results are shown in Table two. In terms of the carbon price on imported petroleum products, the average ad valorem tax rate of 8.88% can be obtained.

Table 2. Equivalent sectoral ad valorem tax rate at 100yuan/tCO2 (%)

Sectors	Coal	Crude Oil and Natural Gas
Agriculture	155.2	0.0
Mining and washing of coal	30.3	0.8
Extraction of petroleum and natural gas	27.1	27.2
Mining and processing of ferrous metal ores	15.8	0.0
Mining and processing of non-ferrous metal ores	13.5	0.0
Mining of other ores	118.3	0.0
Manufacture of foods, beverages and tobacco	57.0	0.1
Manufacture of textile	41.5	0.1
Manufacture of wearing and leather	12.5	0.1
Lumber and furniture	12.4	0.1
Manufacture of paper and paper products	85.8	0.5
Printing, reproduction of recording media	14.5	0.2
Manufacture of articles for culture, education and sport activity	7.5	0.2
Processing of petroleum, coking, processing of nuclear fuel	40.8	7.6
Manufacture of raw chemical materials and chemical products	30.5	6.3
Manufacture of medicines	179.9	0.5
Manufacture of chemical fibers	59.7	0.1
Manufacture of rubber	21.7	0.4
Manufacture of plastics	19.3	0.2
Manufacture of non-metallic mineral products	26.7	0.6
Smelting and pressing of ferrous metals	42.1	0.2
Smelting and pressing of non-ferrous metals	20.8	0.2

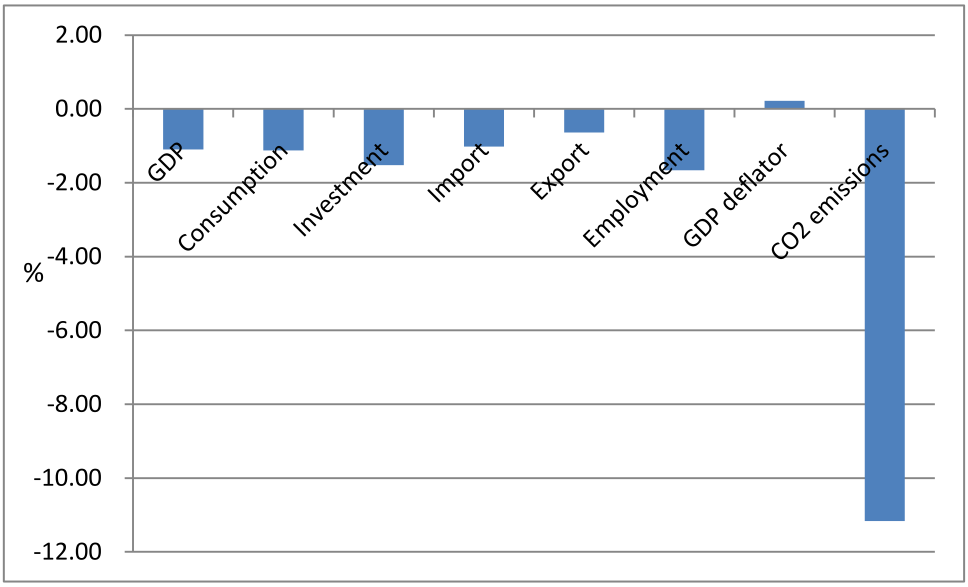
Manufacture of metal products	9.5	0.1
Manufacture of machinery	11.0	0.2
Manufacture of transport equipment	47.5	0.4
Manufacture of electrical machinery and equipment	16.8	0.2
Manufacture of communication equipment, computers and other electronic equipment	42.5	0.5
Manufacture of measuring instruments and machinery for cultural activity and office work	5.0	0.1
Other manufacturing	20.2	0.0
Electricity & Heat	71.1	0.5
Gas production and supply	37.5	0.0
Water production and supply	44.0	0.0
Construction	17.7	0.7
Transport & stock	17.9	4.9
Trade, Accommodation, restaurant	86.7	0.4
Other services	8.5	0.5
Household Consumption	97.6	0.9

3.4.2 Macro economic impact

In order to prevent repeating, we interpret in a detailed manner the short-term impact of S1 which is representative enough for understanding the fundamentals of SIC-GE and then made comparison among scenarios. For clarification, when comparing policy scenarios, the reference scenario is S0 if not specified. The variation of parameters is given in percentage form which indicates the change with regard to baseline (reference scenario S0) level.

The macro economic impacts of carbon price under S1 are shown in Figure three. As seen, under 100 yuan/ton CO2, the negative macro economic impacts are significant: relative to the baseline level, the GDP was reduced by 1.1% (leading to a GDP growth of 13.1% comparing to 14.2% of reference scenario). Consumption decreased by 1.13%. As a result of a decrease of about 3.37% in the real rate of return (ROR), investment is reduced by 1.52%. The introduction of carbon pricing is shown to lead to a real appreciation of about 0.22% relative to the baseline, which contributed to a decrease in exports of 0.64%. Imports were reduced by 1.02% due to the weakened domestic demand. Employment decreased 1.66%. However, such macroeconomic results are not usually easily understood by those unfamiliar with the model. For their benefit, a simplified framework is constructed in Appendix C, which provides a **detailed and comprehensive explanation of the results obtained by SIC-GE**, based on the Dixon and Rimmer approach (2002).

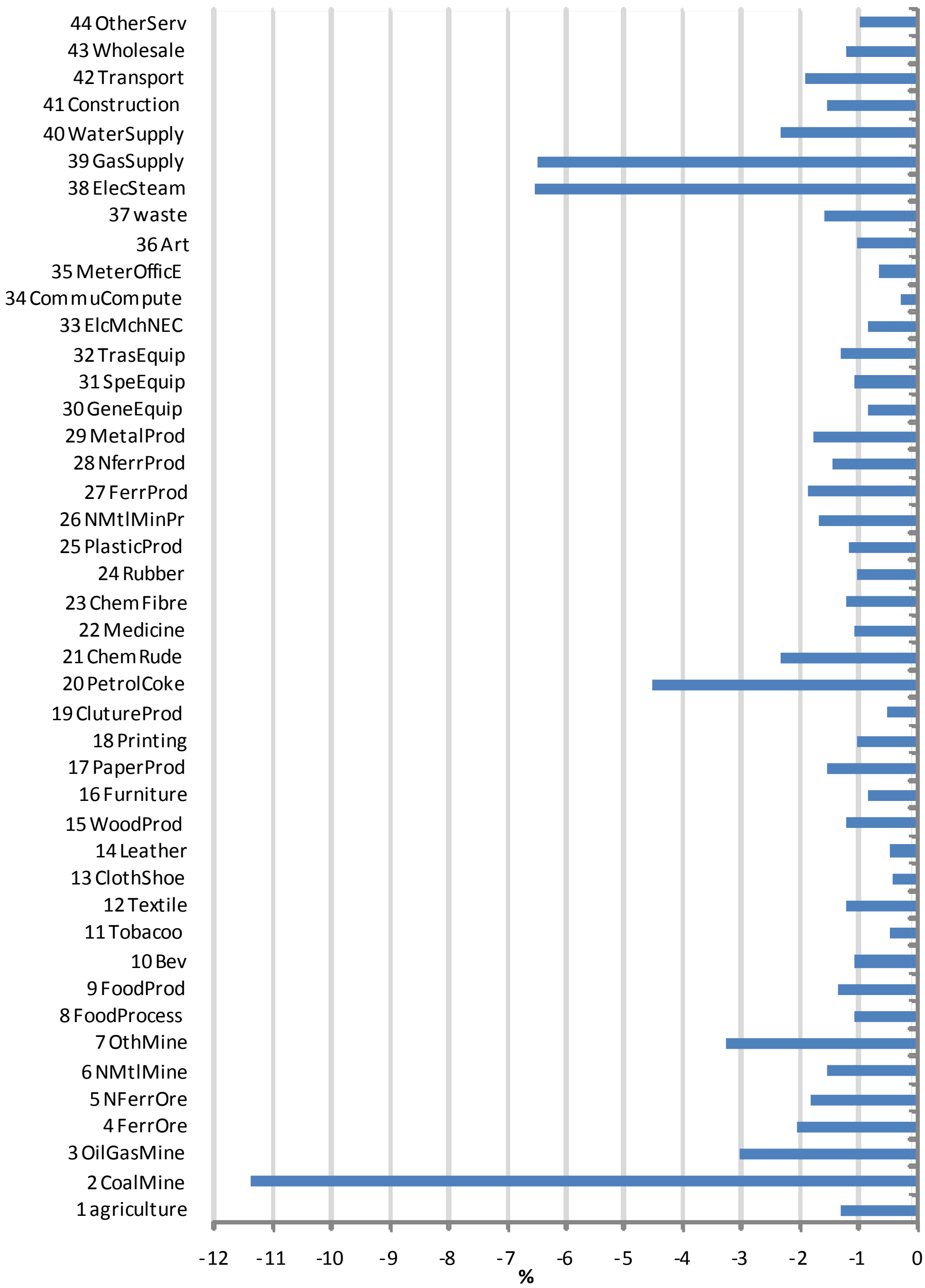
Figure 6. Macroeconomic impact of the carbon price in 2007 under 100yuan/tCO2 (S1)



3.4.3 Impact on industrial output change

According to figure seven, the output of all industries decreased under 100yuan/tCO2 under S1. Particularly and not surprisingly, the output of the energy supply sectors is drastically cut (coal mining (2), electricity power and heating generation (38) and gas supply (39) sectors). The output of major energy intensive sectors is reduced by about 2-3%, while the petroleum refinery and coke sector is one of the most affected sectors, displaying an output reduction of 4.6%. Also, the output of light industries and labor-intensive sectors is reduced by about 1%.

Figure 7. Industrial output changes in 2007 under 100yuan/tCO2 (S1)



3.4.4 Impact on exports

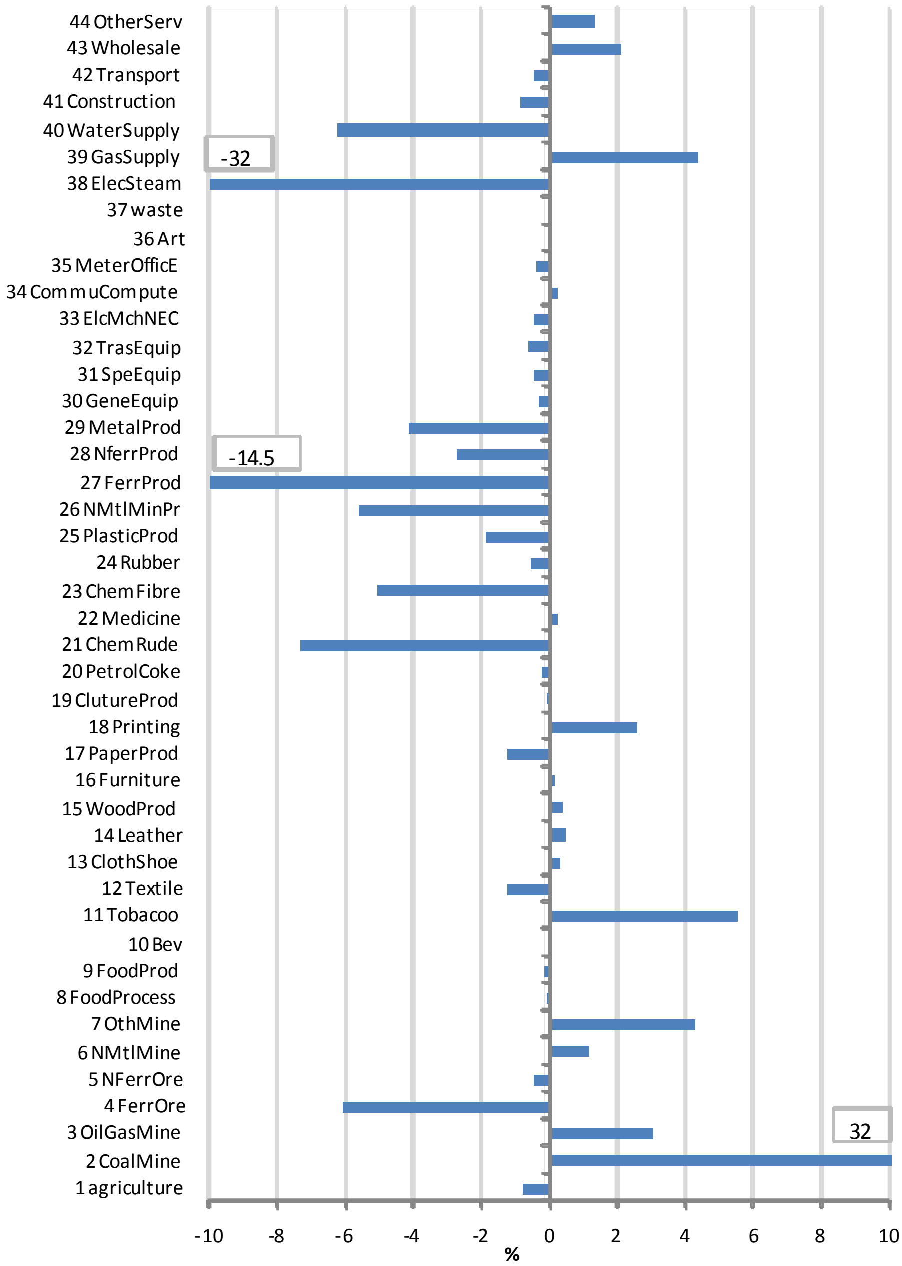
The competitiveness impact, measured in terms of the impacts of carbon cost on industrial exports, differs largely among sectors. As Figure eight shows, the export of most energy intensive sectors will decrease (dramatically) under 100yuan/tCO2. For example, the export of ferrous metal will be the most seriously affected sector, with a reduction of up to almost one third of its total export. This is principally due to its high carbon (energy) intensity as shown in section 4.1.1.

On the other hand, exports of certain sectors are actually stimulated under a carbon pricing policy. For example, energy products (such as coal mine products, oil and natural gas products) and some manufacturing products (including tobacco, printing, computers, clothing and some services) show an increase in exports. Further precision on the price determination mechanism in the model is required to examine this effect in greater detail.

In accordance with the impact analysis on macroeconomic variables in 4.2.3, the general rental of capital goes down by about 3.2%. At the sectoral level, the extent of such a reduction is much greater for energy producing sectors. While the rental of capital in the coal mining sector, which has reduced by 27.8%, is one of the most affected sectors. According to the market clearing principle and given that the general price of coal mining products mainly includes the cost of primary factors and intermediate inputs, the reduction of the capital rental price will reduce the base price of coal products. In consequence, this reduction will generate a decrease in the FOB coal price, and finally lead to the increase of its export. This mechanism can also explain the export increase of oil and natural gas following the introduction of a carbon price of 100yuan/tCO2.

For non-energy product sectors showing an export increase, their ratios of the cost of capital to total cost explain why exports have increased following the implementation of a carbon pricing policy in China. In 2007, for example, in the printing, tobacco and service sectors this ratio was, respectively, 19.1%, 34.1% and 24%, all of which are above the general average value for all sectors (15%). The base price increase due to carbon costs will be compensated by the effect of a base price decrease through the above-mentioned capital rental mechanism. Therefore, for these sectors, the ultimate impact of introducing a carbon cost will be to cause a base price decrease that will contribute to an export increase.

Figure 8. Change in industrial exports in 2007 under 100yuan/tCO2 (S1) (%)

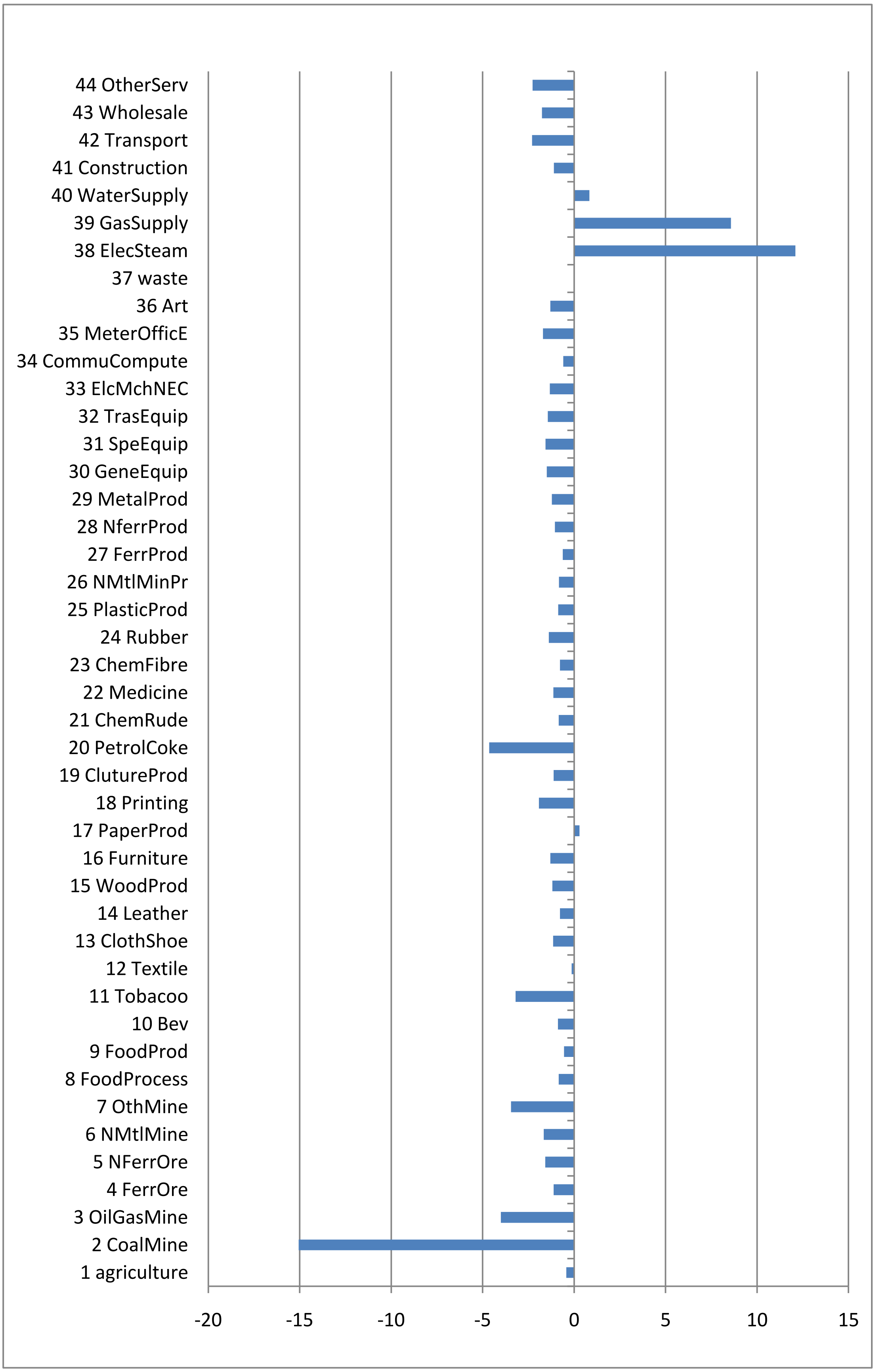


Source: SIC-GE.

3.4.5 Impact on imports

The import of fossil fuels decreased as the impact of carbon price imposed. The import of electricity and gas supply increases and this is due to the assumption that there is no carbon price implemented on such imports. The import of other manufacturing sectors decreased. This is basically due to a net result of import demand increase (due to consumption on imports) and decrease (due to investment using imports). As seen, only the import of paper production sector increases which might generate slight carbon leakage problems.

Figure 9. Change of industrial imports under 100yuan/tCO2 (%)

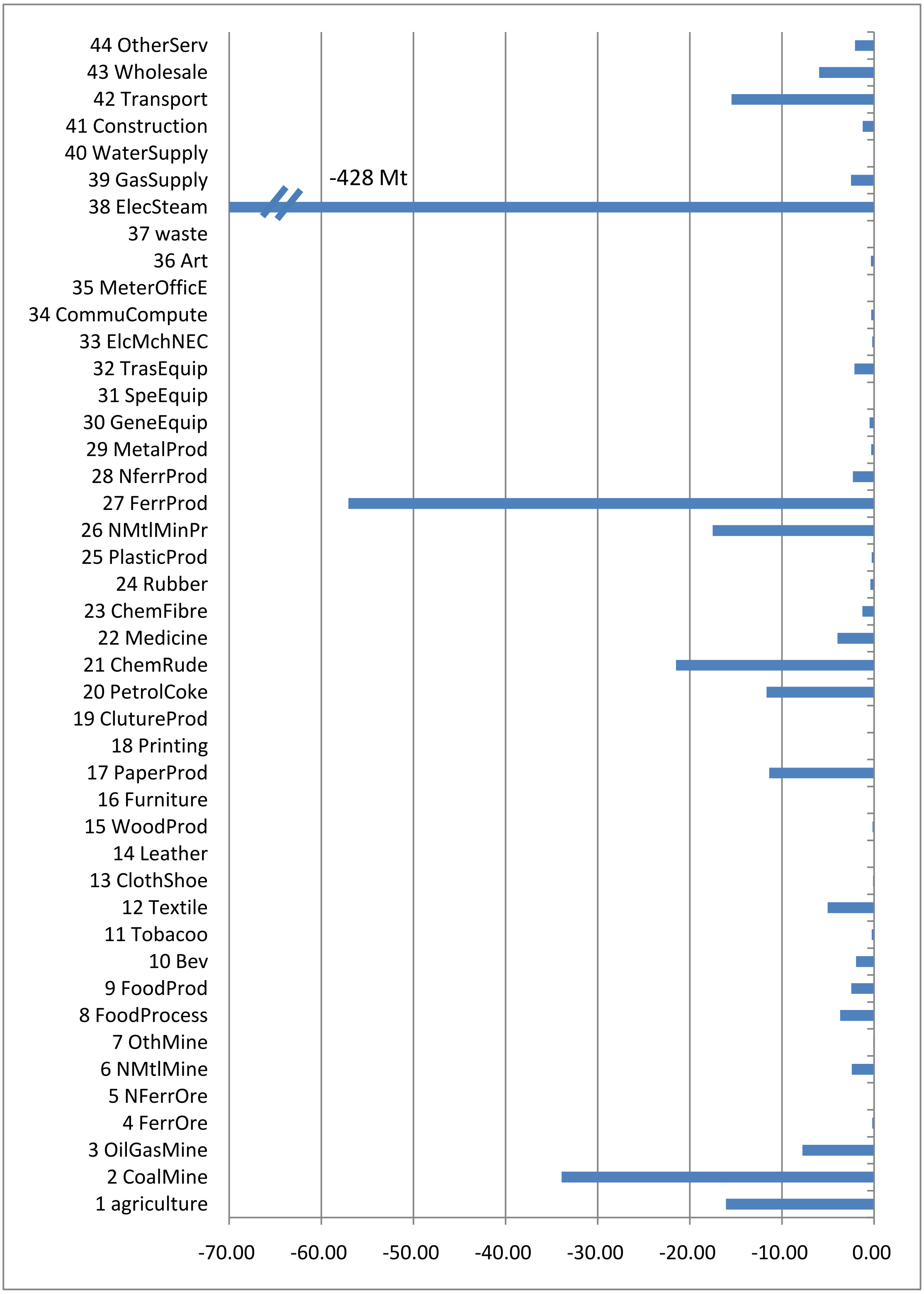


Source: SIC-GE.

3.4.6 Impact on CO2 emission

The CO2 emission reduction effect is significant under 100yuan/tCO2 under S1. According to the model, the total reduction in CO2 emissions will be 661.46 million ton, corresponding to an 11.16% reduction relative to the baseline scenario. A reduction in the domestic consumption of coal mining products, which decreased by 12.5% relative to the baseline case, provides the major contribution towards total CO2 emission reduction. The electricity and steam supply sector is particularly significant, with a reduction of coal consumption together with other fossil fuels accounting for a CO2 emission reduction of 428 million ton of CO2 (see figure ten). This finding corresponds to the sector's high carbon intensity, shown in figure one. The second greatest contributing factor to the decrease of CO2 emissions is the emission reduction of (heavy) industrial sectors (such as ferrous metal, chemical products and coke, etc.). While the major absolute reductions of CO2 emissions occurred in energy-intensive sectors, the highest CO2 emission reduction in percentage terms relative to the baseline scenario was provided by the medicine sector (-36%). This is principally due to the high equivalent ad valorem carbon tax rate that the carbon price would generate (cf. table 2).

Figure 10. Sector CO2 emissions[41] reduction in 2007 (MtCO2)



Source: SIC-GE.

[41] The CO2 emissions for a sector only involve the CO2 emissions from direct fuel consumption.

3.4.7 Comparison of different revenue redistribution scenarios

Table 3 compares the macroeconomic impacts of 100yuan/tCO2 on major economic and climate indicators among policy scenarios. As seen, S5 can be considered the best option among scenarios provided here in terms of short-term impact (yet will not be a final option as will be shown below in long-term impact comparison). The positive GDP growth under S5 is due to the high growth of consumption which compensates the negative GDP growth impact generated by carbon price. The high consumption growth has also generated positive employment rate and import growth. Comparing S1, S2 and S3, the zero carbon cost pass-through for electricity sector could reduce the negative macroeconomic impact but also ensure lower CO2 emissions reduction level due to different levels of electricity output (the output of electricity and heat production sector will reduce respectively 3.45% and 0.35% in S2 and S3, comparing 6.56% in S1).

Table 3. Comparison of different scenario (%)

	S1	**S2**	**S3**	**S4**	**S5**
GDP	-1.10	-0.82	-0.56	-0.46	0.22
Consumption	-1.13	-0.84	-0.57	-0.58	1.50
Investment	-1.52	-0.90	-0.26	-0.13	-0.27
Import	-1.02	-0.75	-0.48	-0.18	0.11
Export	-0.64	-0.69	-0.79	-0.48	-0.91
Employment	-1.66	-1.23	-0.80	-0.42	1.07
GDP deflator	0.22	0.31	0.44	0.32	-0.71
CO2 emissions	-11.16	-9.00	-6.75	-9.97	-10.14

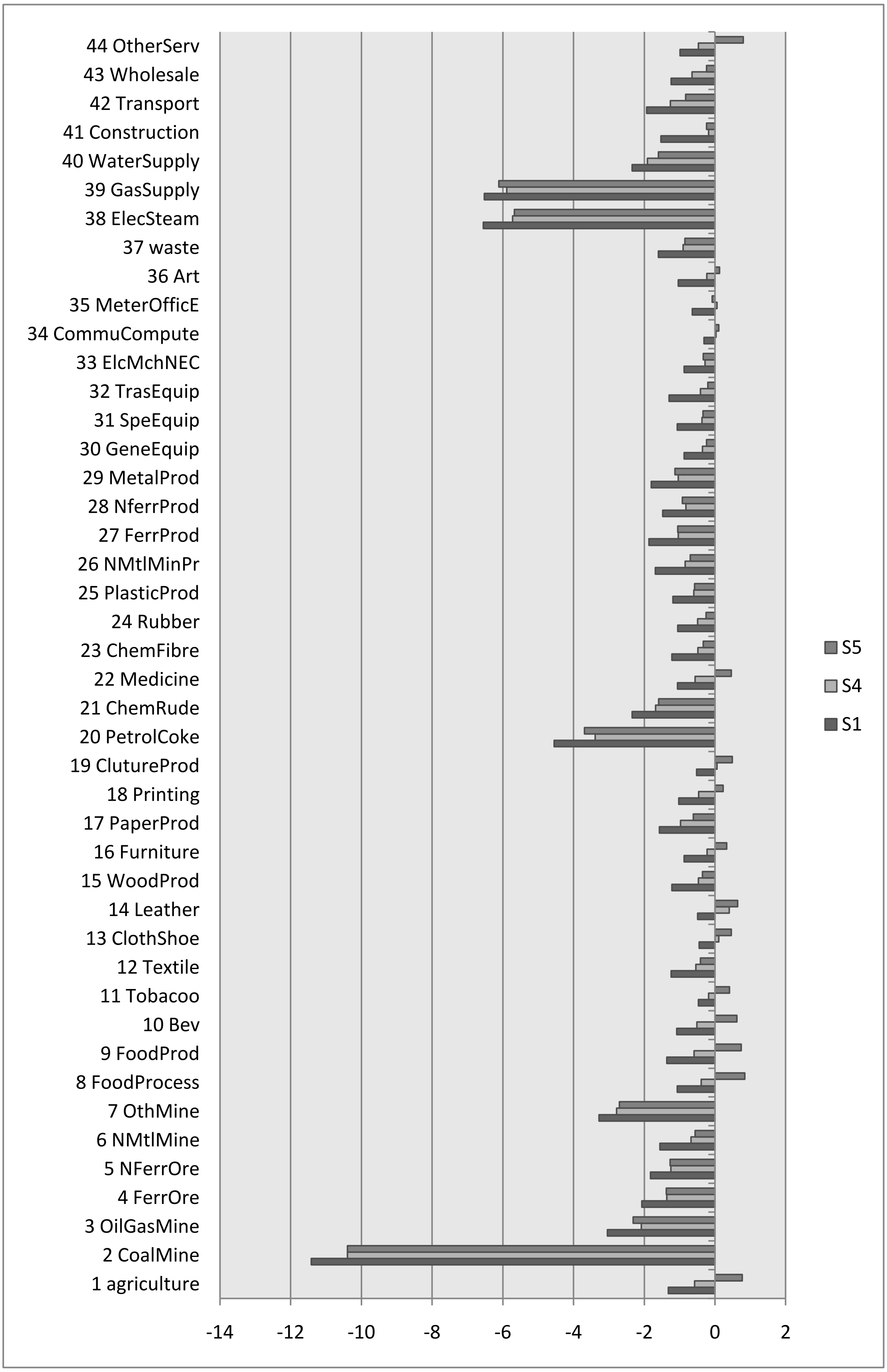
Source: SIC-GE.

In the attempt to compare model results of different carbon revenue redistribution modes, only S1, S4 and S5 are adopted for sectoral level comparison. As figure 11 shows, the sectoral output of most of the sectors providing consumption goods (such as agriculture, food production, cloth and shoes, etc.) have achieved an increase relative to reference scenario under S5. This is due to the increasing consumption demand as a result of consumption price decrease. Yet, the output of most energy-intensive sectors (ferrous metal, basic chemical, etc.) still decreased due to the fact that these sectors are major suppliers for investment of which the demand decreased as a result of investment product price increase.

In terms of export change comparison among the same three scenarios (figure 12), most of the sectors have followed the same trends. Yet the export of major consumption product sectors (cloth and shoe for example) has decreased in S5 different to S1 and S4 and a result of the eviction effect of domestic increasing consumption which has driven a higher export price on such products.

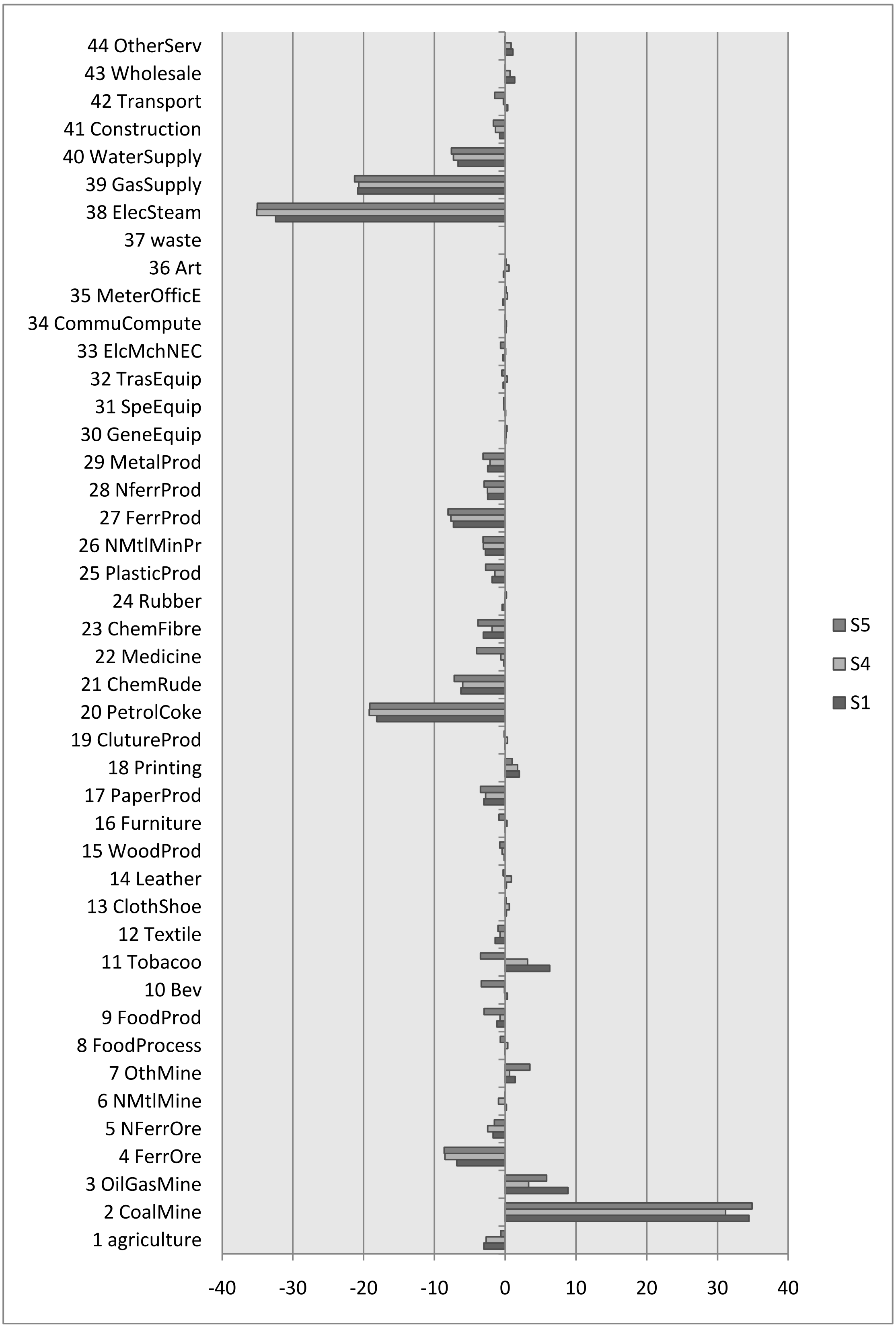
In a similar logic, the sectoral import change comparison among S1, S4 and S5 have shown the same import change trends among sectors and scenarios. Yet the import of major consumption product sectors (cloth and shoe for example) has increased due to domestic consumption increase under S5.

Figure 11. Industrial output change comparison: S1, S4, S5 (%)



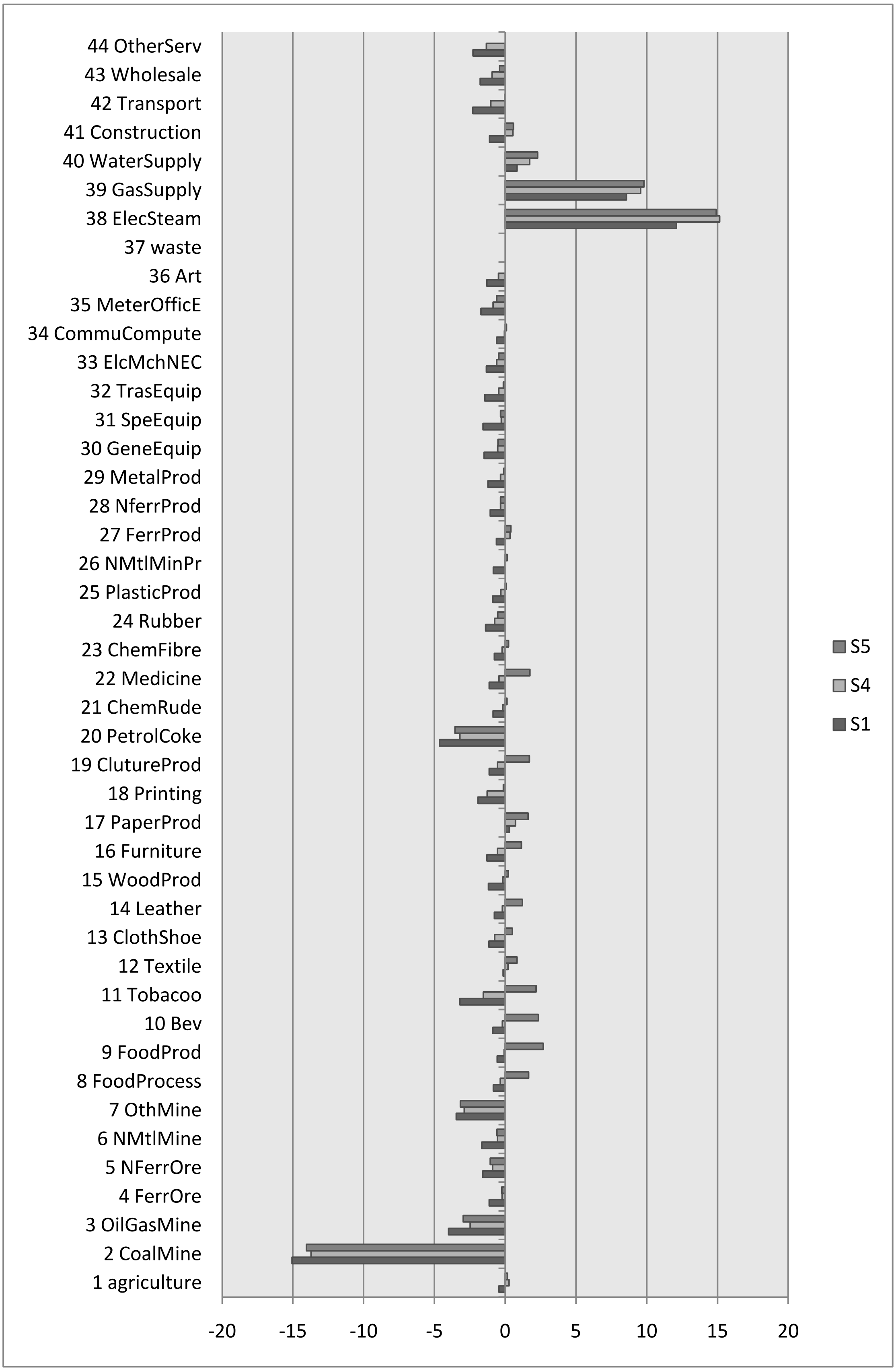
Source: SIC-GE.

Figure 12. Export change comparison: S1, S4 and S5 (%)



Source: SIC-GE.

Figure 13. Import change comparison: S1, S4 and S5 (%)



Source: SIC-GE.

3.4.8 Long-term impact analysis

3.4.8.1 Macroeconomic parameters

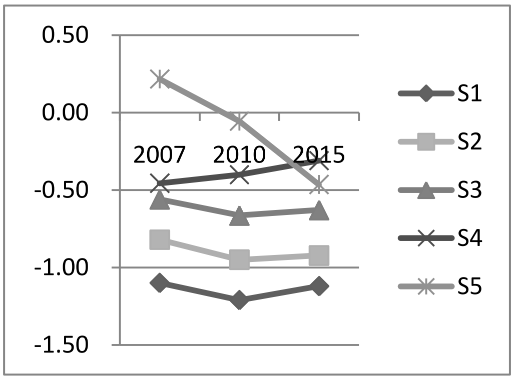
In terms of GDP impact, figure 14 shows that the long-term GDP impact of S1, S2 and S3 has similar trends which will decrease after the introduction of the carbon price and slightly recover since 2010 (by considering the real 2008-2009 global economic crisis). Under S4, the negative GDP impact is smaller and decreases as a result of increasing employment (figure 15) and investment (figure 16) in the long-term. Strikingly, under S5 which is the most recommended scenario according to the short-term analysis, the long-term GDP impact is decreasing. This is principally due to the following reason: the decreasing price of consumption goods increases the demand for consumption which generates substitution effect among investment and export. The price of investment and export products therefore increases. The major impact comes from the investment side. The increasing investment price engenders a decrease of real return of capital and thus reducing the demand for investment. The latter generates a decrease of capital stock which contributes to GDP growth decrease together with the decreasing employment.

Figure 17 shows the long-term consumption impact, as seen the consumption impact is similar among S1-S4 while decreased under S5. The reason for the similar trend of S1-S4 which follows the movement of GDP is due to the assumption that the average propensity of consumption is fixed in the long term. For S5, despite the decreasing consumption, the positive value indicates that the revenue feedback to consumption always contributes to the increase of consumption (although the GDP variation changes from positive to negative).

Figure 18 and 19 show the long-term export and import impacts respectively. As seen, all scenarios will generate moderate export and import decrease with regard to reference scenario. For S4, the revenue feedback to production will reduce the producer price of domestic goods which will contribute to a recovery of export in the long-term. For S5, the decreasing export trend is due to the increase of export price as a result of increasing domestic consumption.

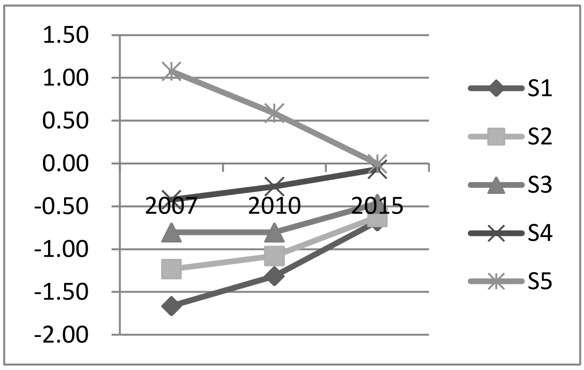
Finally, in terms of total CO2 emissions reduction, all five scenarios follow the same trend. This is principally due to the same technological change assumed by the model for these scenarios.

Figure 14. Long-term GDP impact of 100yuan/tCO2 among scenarios (%)



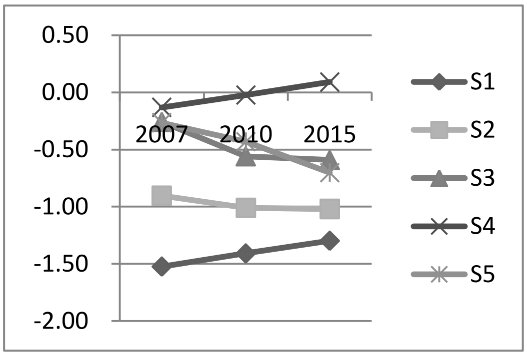
Source: SIC-GE.

Figure 15. Long-term employment impact under 100yuan/tCO2 (%)



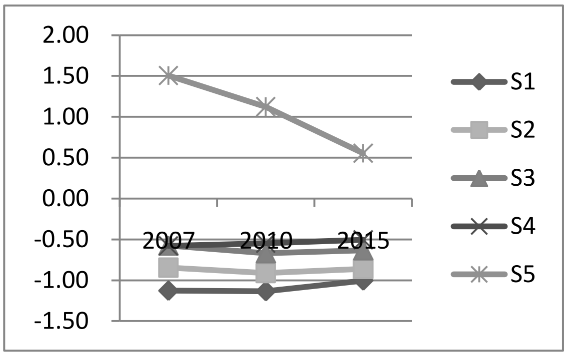
Source: SIC-GE.

Figure 16. Long-term investment impact under 100yuan/tCO2 (%)



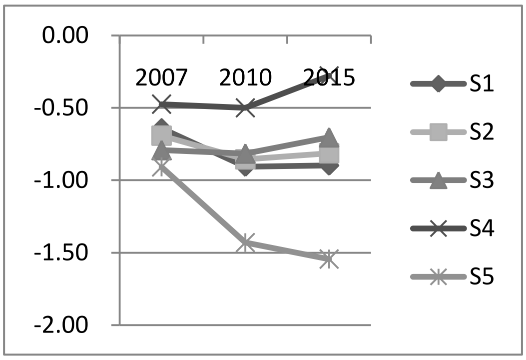
Source: SIC-GE.

Figure 17. Long-term consumption impact under 100yuan/tCO2 (%)



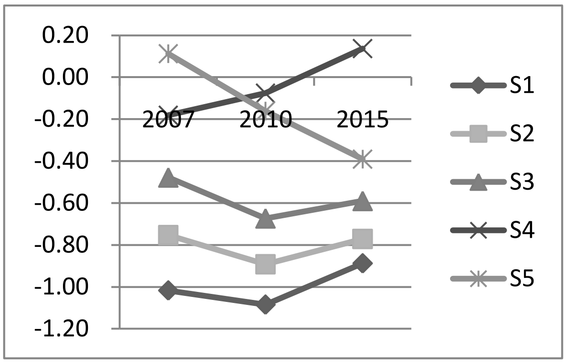
Source: SIC-GE.

Figure 18. Long-term export impact under 100yuan/tCO2 (%)



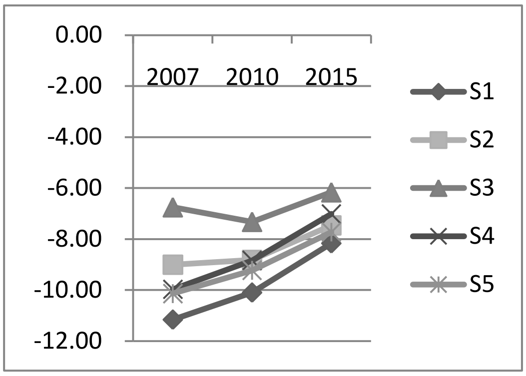
Source: SIC-GE.

Figure 19. Long-term import impact under 100yuan/tCO2 (%)



Source: SIC-GE.

Figure 19. Long-term CO2 emissions impact under 100yuan/tCO2 (%)

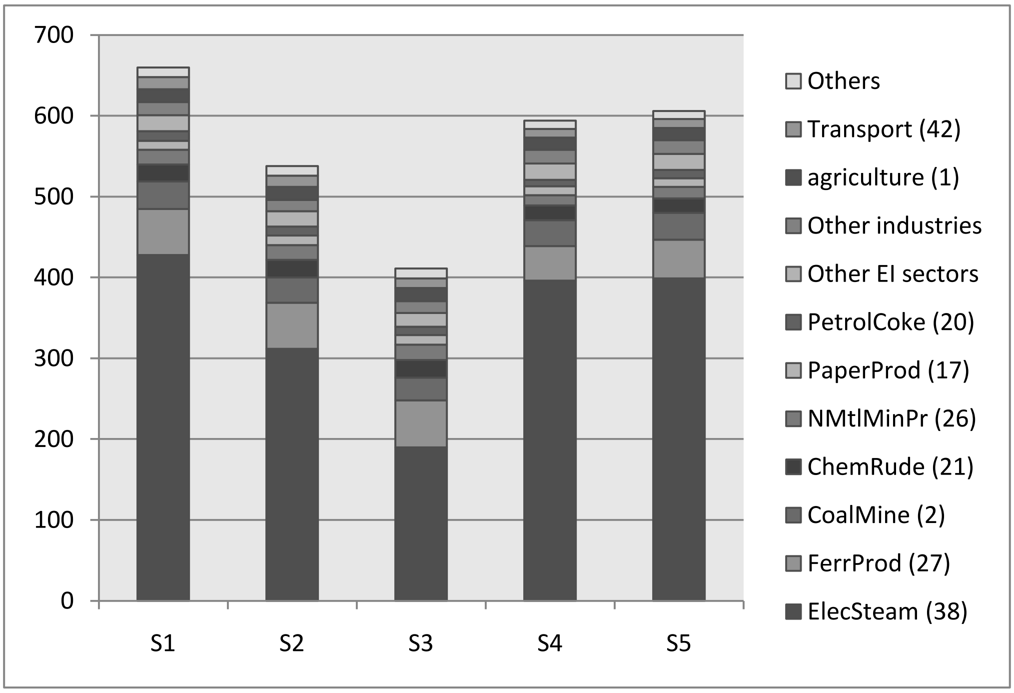


Source: SIC-GE.

3.4.8.2 Sectoral level comparison

Figure 20 shows that among five policy scenarios, most of the CO2 emissions can be reduced from electricity and heat production sector. This is obtained based on real sectoral CO2 emissions due to fossil fuels consumption which are calculated based on 2008 ESY of China. Given that SIC-GE only gives the CO2 emissions reduction percentage with regard to reference scenario, the lack of detailed CO2 emissions data in 2010 and 2015 does not allow us making similar figures reminding that SI-CGE model results show only deviation of variables with regard to baseline scenario in percentage form. Yet according to the SIC-GE model results, the CO2 emissions reduction percentage among sectors follow the same trend in the long-term (cf. figure 19). This could lead to similar figures of major long-term CO2 emissions reduction sectors to figure 20 if sound and viable CO2 emissions data is used for 2010 and 2015.

Figure 20. Sectoral CO2 emissions reduction in 2007 (MtCO2)



Source: SIC-GE based on 2007 real sectoral CO2 emissions from 2008 ESY.

4. Conclusion

This chapter provides a detailed sectoral study by applying two complementary analysis tools. First, the linear static system has shown that a lower carbon cost (10yuan/tCO2, roughly 1 euro/tCO2) could be a safe starting point for introducing a carbon price in China in terms of having a low impact on competitiveness, a conclusion that concurs with the proposals of recent studies on the same topic. In order to level the significance of the carbon pricing impact, we have also adopted a higher carbon cost (100yuan/tCO2, roughly 11-12 Euro/tCO2) under the same approach. In order to provide a comprehensive and more comparable interpretation on the impact of a higher carbon price on Chinese economy, we have adopted the EU Commission's criteria on whether a sector's competitiveness and/or carbon leakage impact is significant. As a result, the competitiveness of nine sectors, representing 13% of total Chinese GDP and 36.9% of total Chinese export (gross value), would be affected and therefore certain sectors might require compensatory measures under such carbon price depending on the choice of the criteria of a seriously impacted sector. This is the first-step result for policy makers when deciding the level of carbon price in China.

However, such a result would not demonstrate any detailed impacts on specific economic and climate parameters (such as GDP, export, CO2 emissions reduction, etc.) which could be key issues for policy making. In order to enrich the policy decision basis, this paper has adopted a CGE modeling analysis by using the SIC-GE model which has conducted several assessments for the Chinese government. By providing the economic and climate impacts of the higher carbon cost of 100yuan/tCO2 (roughly 11-12 euro/tCO2) under different revenue redistribution scenarios where the revenue is not redistributed, redistributed for promoting investment and consumption, the modeling analysis has provided additional information for policy making beside the linear static analysis of which the following points might worth being highlighted.

1) Key contributing sectors to CO2 emissions reduction: The model has shown that electricity sector would be the major contributor to CO2 emissions reduction under carbon pricing policy. For example, under the scenario of non revenue distribution (S1), **total CO2 emissions would decrease 661 Mn tons where 428 Mn tons CO2 are reduced from the electricity sector in 2007** based on real secotral CO2 emissions data. Ferrous metal, basic chemical, coal mining as well as some other energy-intensive sectors are also major contributors of CO2 emissions reduction following electricity sector. This result corresponds to the higher share of carbon cost to sectoral value-added of these sectors that the linear static analysis shows. Further, the relatively limited numbers of principal contributing sectors of CO2 emissions reduction could provide a solid reference when deciding the coverage issue of carbon pricing policies whether in the form of an emission trading system or a carbon tax. Instead of implementing national wide carbon pricing policy, the carbon cost could be assigned to a limited number of energy-intensive sectors and could achieve more or less the same emission reduction target while requesting less implementation and management costs.

2) Sectoral output changes and compensatory measures: The model has demonstrated the sectoral output and export changes under 100yuan/tCO2. As seen, under the same scenario of non revenue redistribution, most energy supply sectors' output decreased dramatically while the output of industrial sectors (including energy-intensive sectors such as ferrous metal, basic chemicals, etc.) decreased within a range of 1-2%. At the export level, most of the energy-intensive sectors' export decreased dramatically yet certain sectors' export increased due to the export price decrease. **The carbon pricing policy could therefore contribute to China's development strategy of curbing the expansion of domestic energy-intensive sectors and the export of energy-intensive products.** However, for certain sectors, compensatory measure(s) might be important if a higher carbon price is implemented. For example, the export of metal product sector could reduce more than 4% according to our model result. The products of this sector usually possess higher value-added and longer process chains and the exemption of carbon cost on their export might be helpful. Further works should therefore focus on specific sectors which could require different compensatory measures if a higher carbon price is implemented.

3) Revenue redistribution under Chinese context: This paper shows that the scenario where the revenue generated by carbon pricing is redistributed to stimulate investment seems to be the best option in terms of welfare and cost-effectiveness among options analyzed in this paper. However, as will also be discussed in the following chapter, **there is so far no specific (tax) revenue redistribution mechanism in China.** How revenue generated by carbon pricing policies can be redistributed under Chinese context could be a key area for research in the next chapter, involving the examination of the economic and political feasibility of different revenue redistribution methods.

References:

Baumol, W., J., Oates, W., 1988. *The theory of environmental policy*, 2nd Ed., Cambridge University Press, Cambridge.

Brenner, M, Riddle, M., Boyce, J.K., 2007. A Chinese sky trust? Distributional impact of carbon charges and revenue recycling in China, *Energy Policy* 35, pp.1771-1784.

Fan G., Cao J., Yang, H.W., Li, L.L., SU, M., 2009. Economic development and low carbon economy: China and the world, paper prepared for the forum Economic Development and Low Carbon Economy: China and the World, Beijing, Sept. 12, 2009.

Grubb, M., Brewer, T.L., Sato, M., Heilmayr, R., Dora, F., 2009. Climate Policy and Industrial Competitiveness: Ten Insights from Europe on the EU Emissions Trading System. *Climate & Energy Paper Series* 09, Climate Strategies, Cambridge.

Hourcade, J.-C., Demailly, D., Neuhoff, K., Sato, M., 2007. Differentiation and dynamics of EU ETS industrial competitiveness impacts. *Climate Strategies Report*, Climate Strategies, Cambridge.

IPCC, 2006. IPCC Guidelines for National Greenhouse Gas Inventories, 2006. Volume 2 Energy.

Jiang, K.J., Hu, X.L., Deng, Y.Y., Zhuang, X., Liu, H., Liu, Q., Zhu, S.L., 2009. Impact of carbon tax and analysis on related issues, in: Hu, X.L., Wang, J.Z., Cen, L.Y., Lei, H.P. (Eds), 2050 China Energy and CO_2 Emissions Report. Science Press, Beijing, pp. 413-445. (in Chinese)

Koopman, R., Wang, Z., Wei, S.J., 2008. How much of Chinese exports is really made in China? Assessing domestic value-added when processing trade is pervasive. *NBER working paper* 14109.

Kuik, O., Hofkes, M., 2010. Border adjustment for European emissions trading: Competitiveness and carbon leakage. *Energy Policy*, 38, pp.1741-1748.

Li, Z., 2003. An econometric study on China's economy, energy and environment to the year 2030, *Energy Policy*, 31, pp.1137-1150.

Liang, Q.M., Fan, Y., Wei, Y.M., 2007. Carbon taxation policy in China: how to protect energy-and-trade-intensive sectors?. *Journal of Policy Modeling*, 29, pp.311-333.

Liu, Z., 2007. *China Taxation*, Economic Science Press, Beijing. (in Chinese)

Mai. Y., 2006. The Chinese Economy From 1997-2015: Developing a Baseline for the MC-HUGE Model. Centre of Policy Studies Monash University Working paper No. G-161.

Ministry of Environmental Protection of China, www.sepa.gov.cn

Ministry of Finance of China, www.mof.gov.cn

Monjon, S., Quirion, P., 2010. How to design a border adjustment for the European Union Emissions Trading System?. *Energy Policy*, 38, pp.5199-5207.

Ngan, H.W., 2010. Electricity regulation and electricity market reforms in China, *Energy Policy*, 38, pp.2142-2148.

Ou, X.M., Zhang, X.L., Chang, S.Y., 2010. Alternative fuel buses currently in use in China: life-cycle fossil energy use, GHG emissions and policy recommendations. *Energy Policy*, 38, pp.406-418.

Stern, N., 2009. *The Global Deal, Climate Change and the Creation of a New Era of Progress and Prosperity*. Public Affairs, New York.

Su, M., 2009. Analysis on the Implementation of Carbon Tax in China, paper presented at International Symposium on a Carbon Tax, Beijing, Sept. 8, 2009.

Su, M., Fu, Z., Xu, W., Wang, Z., Li, X., Liang, Q., 2009. An analysis of the implementation of the carbon tax in China, *Review of Economic Research*, 2009, 72, pp.2-16. (in Chinese)

Wang, B., 2007. An imbalanced development of coal and electricity industries in China, *Energy*

Policy, 35, pp.4959-4968.

Wang, J., Yan, G., Jiang, K., Liu, L., Yang, J., Ge, C., 2009. The study on China's carbon tax policy to mitigate climate change, *China Environmental Science*, 2009, 29(1), pp.101-105. (in Chinese)

Zhang, Z.X., 2010. The US proposed carbon tariffs and China's responses. *Energy Policy*, 38, pp.2168-2170.

Appendix A. Sector division and statistical compatibility of data

In China, sectors are currently classified under the statistical standard GB/T4754-2002[42]. Similar to the NACE system, sectors are designated by a higher case letter, indicating the section name, followed by three numbers: there are 20 sections (from A to T), the first number, which ranges from 1 to 98, indicates the division, the next number represents the group, while the final number further divides the groups into classes. Under GB/T4754-2002, the 2007 Chinese Economy Input-Output (IO) Table divides into 135 sectors. To facilitate our analysis and for clarity, we consolidated these 135 sectors into 36 representative groups for the analysis using the approach developed by Hourcade et al. (2007), as shown in Table A1. The sectors shown are defined according to GB/T4754-2002 down to the group number level. Certainly, the 36 sector division is statistically compatible to and an integrated form of the 44 sector division that ESY used. The only difference between these two sector divisions are that certain service sectors under 44 sectors division are merged into one sector under the 36 sectors division for analysis simplicity given their low energy consumption level.

According to the 2007 IO table of the Chinese economy, the sector value-added is obtained from the "total value-added" row, and the total Chinese GDP is given by the sum of the sectoral value-added. Sector turnover is obtained from the corresponding "gross output" column, and export and import values are obtained from the "exports" and "imports" columns for each sector. The value of imports is calculated according to CIF (Cost, Insurance and Freight) price plus custom duty, and the exports are measured by the FOB (Free On Board) price. All values refer to 2007 producer prices, which includes value-added tax (which is different to the *System of National Accounts* (SNA) 1993).

Table A1. Consolidated sectors, classifications according to GB/T4754-2002 (down to group number)

Sectors	Sectors under GB/T4754-2002
Agriculture, Forestry, Animal Husbandry, Fishery and Water conservancy	A1-5
Coal mining and washing	B6
Oil and gas exploitation	B7
Ferrous metal mining	B8
Non-ferrous metal mining	B9
Other mining	B10-11
Food and tobacco	C13-16
Textile	C17
Clothing, leather and product	C18-19
Lumber and furniture	C20-21
Pulp & Paper	C22

[42] See National Bureau of Statistics of China for detailed information. http://www.stats.gov.cn/tjbz/

Printings and media recording	C23
Education and sport product	C24
Petroleum refining, coking and nuclear materials production	C25
Basic chemicals	C26
Drugs	C27
Chemical fibre products	C28
Rubber products	C29
Plastic products	C30
Non-metallic mineral products	C31
Ferrous metal	C32
Non-ferrous metal	C33
Metal products	C34
Mechanic equipment	C35-36
Transportation equipment	C37
Electronic equipment and machinery	C39
Communication, computer and other machineries	C40
Apparatus, cultural and office equipment	C41
Other manufactures	C42-43
Electricity & Heat	D44
Gas production and supply	D45
Water production and supply	D46
Construction	E47-50
Transport and stock	F51-59
Trade, accommodation and restaurant	H63,65; I66-67
Other services	G60-62; J68-71; K72; L73-74; M75-78;N79-81;O82-83; P84; Q85-87; R88-92; S93-97; T98

Appendix B. Related results

Sector carbon intensity CI_i can be obtained by equation (B1) based on data provided in table B1 where DC_i and IC_i denote respectively the sector's direct and indirect carbon cost to value-added in percentage form, t denotes the carbon tax rate (yuan/t CO_2).

$$CI_i = \frac{DC_i + IC_i}{t \times 100} \quad \text{(B1)}$$

Table B1. Results of related calculations (%)

	A2	A1	A2	A1	GPS	IMI	EXI
Electricity & Heat	2.715	27.153	0.408	4.088	3.311	0.057	0.207
Ferrous metal	1.318	13.183	0.356	3.562	3.044	4.318	9.54
Gas production and supply	1.182	11.829	0.159	1.592	0.083	0	0
Basic chemicals	0.579	5.795	0.327	3.279	2.509	19.869	9.188
Petroleum refining, coking and nuclear materials production	0.732	7.32	0.086	0.86	1.41	6.665	3.529
Non-metallic mineral products	0.49	4.906	0.233	2.334	2.354	1.738	6.837
Non-ferrous metal	0.156	1.566	0.493	4.933	1.439	12.259	6.796
Chemical fibre products	0.229	2.294	0.302	3.029	0.27	4.818	5.983
Pulp & Paper	0.301	3.018	0.188	1.889	0.682	7.193	3.632
Coal mining and washing	0.359	3.594	0.106	1.067	1.664	2.001	2.434
Water production and supply	0.012	0.122	0.316	3.168	0.206	0	0
Rubber products	0.081	0.816	0.235	2.351	0.331	8.386	41.922
Transport and stock	0.258	2.586	0.027	0.275	5.631	3.741	13.664
Textile	0.082	0.829	0.18	1.802	1.847	4.597	46.157
Ferrous metal mining	0.049	0.495	0.199	1.99	0.453	43.474	0.011
Non-ferrous metal mining	0.025	0.258	0.167	1.673	0.36	34.577	2.182
Metal products	0.026	0.265	0.144	1.446	1.385	3.968	24.155

Other mining	0.075	0.759	0.088	0.889	0.567	7.507	3.759
Oil and gas exploitation	0.12	1.203	0.042	0.429	2.141	38.125	1.147
Plastic products	0.026	0.263	0.133	1.331	0.847	5.847	12.383
Drugs	0.049	0.493	0.065	0.652	0.774	5.881	9.838
Food and tobacco	0.05	0.509	0.048	0.483	3.825	3.814	4.611
Mechanic equipment	0.04	0.401	0.058	0.584	3.426	17.266	14.063
Transportation equipment	0.031	0.312	0.051	0.512	2.414	9.184	10.037
Lumber and furniture	0.027	0.272	0.053	0.537	0.982	3.059	27.426
Education and sport products	0.015	0.156	0.058	0.583	0.233	10.252	136.063
Apparatus, cultural and office equipment	0.011	0.113	0.062	0.629	0.287	76.221	39.861
Electronic equipment and machinery	0.012	0.122	0.058	0.581	1.739	14.455	28.722
Communication, computer and other machinery	0.009	0.092	0.055	0.555	2.558	45.134	59.198
Agriculture, Forestry, Animal Husbandry, Fishery and Water conservancy	0.036	0.362	0.026	0.265	10.772	4.604	1.317
Printing and media recording	0.01	0.101	0.052	0.521	0.42	2.074	5.554
Other manufacture	0.014	0.149	0.044	0.443	2.007	16.584	23.015
Clothing, leather and related products	0.017	0.178	0.038	0.387	1.515	4.679	43.606
Trade, accommodation and restaurant	0.021	0.214	0.031	0.315	8.607	1.327	12.032
Construction	0.02	0.202	0.016	0.165	5.455	0.353	0.653
Other services	0.011	0.111	0.02	0.203	24.434	3.621	3.871

Appendix C. Framework for model result explanation

Based on the definition of the marginal product of labor and capital, equations C1 and C2 can be obtained

$$\mathrm{RW} = \frac{\mathrm{P_{GDP}}}{\mathrm{T}*\mathrm{P_C}} * \mathrm{MPL(K,L)} \quad \text{(C1)}$$

$$\mathrm{ROR} = \frac{\mathrm{P_{GDP}}}{\mathrm{T}*\mathrm{P_I}} * \mathrm{MPK(K,L)} \quad \text{(C2)}$$

where RW denotes the real wage, ROR denotes the real rate of return of capital, $\mathrm{P_{GDP}}$ denotes the GDP deflator, $\mathrm{P_C}$ denotes the consumption price, $\mathrm{P_I}$ denotes investment average price, MPL and MPK denote respectively the marginal product of labor and capital which are a function of labor L and capital K, T denotes the power of general tax on GDP.

(C1) and (C2) can be written by the percentage change form as equations (C3) and (C4). The variables noted in lower case indicate the percentage change form of the relative variables in (C1) and (C2).

$$\mathrm{rw} = \mathrm{p_{GDP}} - \mathrm{p_C} + \mathrm{mpl(k,l)} - \mathrm{t} \quad \text{(C3)}$$
$$\mathrm{q} = \mathrm{p_{GDP}} - \mathrm{p_I} + \mathrm{mpk(k,l)} - \mathrm{t} \quad \text{(C4)}$$

For the marginal product of labor or of capital, the percentage change form can be obtained by adopting CES (Constant Elasticity Substitution) function. This leads to the final form as follows:

$$mpl = \frac{S_k}{\sigma}(k-l) \quad \text{(C5)}$$

where, $S_k = \dfrac{\delta K^{-\rho}}{\delta K^{-\rho} + (1-\delta)L^{-\rho}}$, and $\sigma = \dfrac{1}{1+\rho}$.

S_k can be seen as the ratio of capital return on total primary return (mainly GDP) and σ denotes the substitution elasticity.

Furthermore, the policy shock can be assumed to generate no effect on technology progress in the short term. The percentage change of GDP (in percentage forms given by lower case letter) can be written as follows (by omitting the change of tax revenue):

$$\mathrm{gdp} = \mathrm{S_L} \times \mathrm{l} + \mathrm{S_K} \times \mathrm{k} \quad \text{(C6)}$$

where gdp, l and k denote respectively GDP, labor and capital changes, SL and SK denote respectively the share of labor and capital to GDP.

Roughly according to the SIC-GE model estimation, there were about 5.77 billion ton CO2 emission from the primary energy consumption and imported secondary petroleum product. A carbon cost at 100 yuan/tCO2 could generate 577 billion yuan, which would account about 2.17% total GDP (26581 billion yuan) in2007.

According to (C3) and (C5), by assigning 2.17% to t, small relative change of GDP deflator on consumer price level (pg-pc=-0.01%), with the general substitution elasticity at 0.5, the share of capital at 0.535 (calculated according to the data in row 8, Table 1), with the short-term fixed real wage assumption, the change of employment is obtained at -2.03%, which is close to the model result -1.66%. The difference is caused by principally the industrial structure change due to higher impact of carbon cost on energy-intensive sectors.

According to (C6), if capital stock is assumed to be indifferent to carbon cost in the short term, the change of GDP will be generally generated by the unemployment. As a result, the GDP loss according to the simplified framework reaches roughly to 0.77%. This is lower than the result of the model (-1.1%) as the simplified framework does not account the welfare loss due to the implementation of the carbon pricing policy.

Chapter Four. Uncertainties and key issues for a successful implementation of domestic carbon price

1. Introduction

We have demonstrated the carbon price impact in China in Chapter Three which provided a solid scientific basis for policy making. Not surprisingly and usually, there would be uncertainties and barriers for a short-term implementation of a new policy despite the official willingness of introducing carbon pricing policies in China. It takes usually a long administrative process from policy proposal obtained from models and analyses to real policy implementation. So far, most of the studies on carbon pricing policies in China have focused on quantitative impacts[43]. There exist some studies on the feasibility or guidelines of implementing specific forms of carbon price (Chang and Wang, 2010; Cong and Wei, 2010; Hu, 2009). Yu (2010) examined institutional structure on energy governance in China. Zhou et al. (2010) overviewed the Chinese fiscal policies for energy efficiency. However, existing literature rarely discusses in a complete manner the uncertainties and barriers of implementing carbon pricing policies in China.

The objective of this chapter is to demonstrate principal uncertainties and potential barriers and provide recommendations in order to accelerate and ensure a successful implementation of a domestic carbon pricing policy in China. This chapter is organized as follows: Part Two shows the potential legislative barriers related to carbon pricing policy implementation; Part Three discusses the uncertainty on the specific form of carbon price; Part Four assesses the existing pricing policies on fossil fuels by calculating the implicit carbon price and then shows some alternatives of introducing carbon price; Part Five discusses coordination and the revenue use before concluding.

2. Potential legislation barriers

The implementation of a national wide carbon pricing policy as a public policy will require making laws or regulations based on existing laws. According to article 3 of *China's Tax Administration Law*, the implementation, abolishment and modification of a tax must be pursuant to related law. Currently, the *Legislation Law* together with the *Ordinance Concerning the Procedure for the Formulation of Administrative Regulations* defines the framework in which a new tax could be established by law. In addition, the implementation of all (tax) laws needs to be approved by the Congress of China. So far, there are no specific climate change laws in China and the legislative framework related to climate change is fragmented in other laws (for example, *Circular Economy Law*, *Energy Conservation Law*, etc.) or national programs which usually give non legally binding orientations (for example, *China's National Climate*

[43] See introduction of Chapter Three for related references.

Change Programme). Not surprisingly and quite commonly, the making of new laws or the amending of existing laws for implementing new policies could be very tedious and the results could remain very risky and uncertain.

The Chinese case could be illustrated by an example of the implementation of the fuel tax in China. As depicted in a detailed manner by table A1 of Appendix, **the initially proposed fuel tax in 1997 was finally introduced in 2009 but was implemented in a very different form than what was initially designed**. In 1997, the *Road Law* approved by People's Congress included the clause of changing "road maintenance fee" into "gasoline added fee". During the first year of his mandate, China's Premier ZHU Rongji in 1998, proposed to convert fees into tax in order to centralize the revenue collection function of the central government. Particularly, he recommended taking fuel tax as the pilot project which required abolishing related fees (such as road maintenance fee) collected at the time by Ministry of Transportation (MOT) and local governments, and transforming them to tax which would be collected by State Administration of Taxation (SAT) and managed by Ministry of Finance (MOF) of China.

Not surprisingly, such tentative has been repeatedly delayed given such conflict interests among tax payers, tax collectors and tax levying procedures (see table A1). In 1998 October, the State Council solicited twice the Congress to review the revised version of Road Law which includes the clause of changing fuel added fee into fuel tax and received only refusals. After great coordination works, in 1999 October, the 12th meeting of the 9th Conference of the Standing Committee of National People's Congress has finally approved the revised *Road Law* which defines the suppression of related road maintenance fees after the implementation of the fuel tax. However, despite the continuous official releases of confirmation, only more than a decade later, the so-called fuel tax was finally implemented, but, not in its original form. Instead of being a tax item as it was initially designed, it was integrated into the consumption tax by increasing the consumption tax rates on gasoline, diesel and aviation kerosene, defined by the *Notice on the Implementation of the Reform of the Price of Final Oil Products Price and Fees*[44], published in December 2008.

Certainly, the contexts of the fuel tax differ to those of the carbon pricing policies. The former is selected as a test for the general fee-to-tax reform, while the latter has a particular importance for a better development of the low carbon economy. Particularly, the fact that such carbon pricing policies have been written into the 12th FYP (2011-2015) could provide evidence of the larger political and social implications of carbon pricing policy. A shorter legislative process of implementing carbon pricing policy could be anticipated given high political expectation and willingness both at national and local levels of developing low carbon economy. The fuel tax serves merely as a **reference for the legislative uncertainty** of implementing new carbon pricing policy in China.

[44] See the State Notice Guo Fa (2008), No.37.

In addition, if implemented at provincial or city level instead of national wide, the carbon pricing policy in the form of emissions trading system (ETS) would not require obligatory procedure of making laws or regulations based on existing laws. The central government could instead introduce a command-and-control policy which assigns emissions reduction targets to local firms. And local firms would then participate voluntarily to ETS in order to achieve their emission reduction targets. To the contrary, carbon pricing policy in the form of carbon tax would require related laws no matter if it is implemented at national or regional level. This specific form issue of carbon price leads us to the following section.

3. Uncertainty of specific forms of carbon price

3.1 Comparison of carbon tax and emissions trading system

In theory, carbon tax (CT) and emissions trading system (ETS) could achieve the same emission reduction target. The comparison of these two instruments has been conducted by several studies where the analysis of Weitzman (1974) is of particular contribution. The latter compares quantity regulation and taxation under uncertainty. The marginal cost of reduction is known by each firm while this (together with marginal damage) is not available for the government. Such cost is subject to uncertainty and increases with the level of total accumulated emissions. Two well known instruments are given: the quantity regulation (of emissions) introduces the quantity of emissions that a firm can produce, whereas an emission tax ("price" in Weitzman's language) regulate the per unit emission price. Under uncertainty, the optimum can only be obtained by chance: a tax can fix a too high or too low price while quantity regulation may specify a too high or too low emissions level in terms of cost-effectiveness. Weitzman demonstrates that tax is better when marginal control cost curves are steeper than the marginal damage curve and quantity control is preferable in the converse case.

Yet in Weitzman's analysis the tax is linear and fixed for all time, Kaplow and Shavell (2002) have conducted further analysis and extended to permit schemes. They argue that permit markets generate a price which cannot be done by less cost-effective command-and-control policies, although the quantity is fixed by the authority. The government can learn whether firms' marginal costs exceed or fall short of the marginal benefit of emissions reduction with a given target. They also illustrate diverse options that the emission trading scheme can be adjusted to achieve similar second-best optimum generated by a tax (which is either explicitly non-linear or adjustable). They conclude a duality between non-linear tax and adjustable-quantity permits where the firms' information about their costs is harnessed, so that each firm's marginal cost is equal to marginal benefits.

Beyond the economic fundamentals, CT and ETS have both comparative advantages and disadvantages in the real world beside the price-quantity arbitrage. There exist numerous studies on "practical sides" of CT and ETS (for example, Ellerman et al., 2010; Tietenberg, 2006; Zhang and Baranzini, 2004; Ekins and Barker, 2002). Briefly, the policy design is crucial for both measures. Political considerations such as the comprehensibility and public acceptability play also an important role. Finally, in terms of implementation costs, ETS could be more costly to implement at national wide, and would be difficult to abandon once implemented. The implementation of CT could be temporary but will require making related laws or regulations if related laws exist already. Table one summarizes.

Table 1. General comparison of CT and ETS

	CT	**ETS**
Advantage	Predictable price Easy to be understood Revenue redistribution	Predictable emissions Fewer political obstacles Revenue redistribution
Uncertainty	Politically risky (to be implemented) Emission uncertainty (tipping point) Good use of revenue Tax rate progressivity	Unknown price Learning process/cost at the beginning. Over allocation Market imperfections Need price safety valve? Windfall profits
Case studies	Congressman Pete Stark introduced a carbon tax bill in Congress which would impose \$10/ton on carbon content of fuels, beginning in 2008, and increase the tax by \$10/ton each year until US carbon emissions are reduced by 80%. **But,** \$10/ton is equivalent to about 3 cents per gallon of gas. So the first year, gas prices would rise by 3 cents; over the first decade, by 30 cents; over 20 years, by 60 cents. That is less than the probable rate of inflation, and will not depress consumption at all.	EPA's Acid Rain program (SO2), The South Coast Air District (RECLAIM program), EU ETS. **But,** the SO2 market achieved reductions, but not necessarily faster or cheaper than a regulatory system would have achieved it. RECLAIM inflated baselines and, allowed too many imported credits and exemptions to the cap. ETS's over-allocation of permits to selected companies led to windfall profits for those companies, and few emission reductions.

Source: Author's rearrangement based on related sources.

3.2 Review of CT and ETS discussions in China

The studies on the use of CT and/or ETS as a cost-effective measure for reducing the CO2 emissions in China prospered in recent years. The implementation of both has been proclaimed by (different) officials. Table A2 of Appendix provides detailed results of recent works proposing CT or ETS in China. In general, proposals favoring

CT can be summarized by the followings:

- Some ministerial studies have suggested implementing CT for environmental concern (proposed by researches of **Ministry of Finance**).
- Some **policy councilor** has announced to implement CT as part of the environmental taxation reform[45].
- Beside the use of CT for domestic concerns, some **scholar** has suggested implementing CT as a measure to prevent China from being imposed a border carbon tax by developed countries, particularly the EU, during the last couple of years[46].

Comparing to CT, the implementation of ETS has been proposed by different groups of institutions:

- **NDRC** official has clearly pronounced in April 2011 the official program of introducing ETS pilot programs by 2013 and implementing national wide ETS by 2015[47].
- Some official from the **bank system** as well as scholars have also favored ETS which could grant China the price making rights on the global carbon market and provide China an important role on global financial market (See table A2 of Appendix).

It could be recalled that the 12th FYP (2011-2015) has clearly written that China would effectuate gradually an implementation of ETS. To the contrary, the 12th FYP does not mention CT and there is so far no official release of implementing CT. However, as mentioned above, the researches on CT have been conducted at ministerial level and the CT could very probably be a component of the environmental taxation reform which has been clearly written into the 12th FYP. This could enhance the possibility of a short-term implementation of CT.

Nevertheless, detailed works are needed for both CT and ETS in order to ensure a good implementation and functioning. For the CT, there remain several key areas:

- To fix the tax level. The lesson drawn from the pollutant charges (fees) on SO2 and COD is that the level of fees is too low and therefore firms would prefer to pay for the fees and continue to pollute[48]. Beside the economic and climate impacts of carbon prices that Chapter Four has demonstrated, the real behavior change at firm level could also be important in order to ensure the climate efficiency.

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[45] See "Carbon tax could be implemented soon", http://www.cs.com.cn/cqzk/02/201006/t20100601_2454830.htm (in Chinese).
[46] See "China should implement carbon tax", http://jjckb.xinhuanet.com/gnyw/2009-09/09/content_179725.htm (in Chinese).
[47] See "China Plans national emissions trading by 2015", April 11, 2011, Reuters, http://uk.reuters.com/article/2011/04/11/china-carbon-trading-idUKL3E7FB1Q320110411.
[48] See "A too low pollutant fee", available at http://www.china.com.cn/chinese/huanjing/268019.htm(in Chinese)

- To determine whether to impose CT on production (primary energies) or consumption (end-use fossil fuels).

For the implementation of ETS, some key priorities could be:

- The lesson learned from some pilot programs of SO2 emissions change market which have been implemented in previous years is that an ETS must provide sufficient incentive and/or imperative and/or facilities for firms to exchange. This is so far not the case for the current voluntary emissions exchange programs where the engaged firms merely register and proceed to little emission quota exchange. The implementation of an ETS should thus prepare for such trading incentives.
- ETS must ensure a sufficient large scale in terms of CO2 emissions but a limited number of installations in order to be manageable. The choice of the sector should lean on long-term objectives of emissions cap. Therefore, the electricity as well as manufacturing industries sectors might be of sufficient interest (cf. transport and household sectors where the introduction of an emissions cap in forms of ETS could be more difficult).
- To determine its relation with and draw lessons from the total load control policy. China has set total load control policy since the 9th FYP (1996-2000) on pollutants like SO2, solid, etc. in regional wide. During the 11th FYP, SO2, COD became mandatory target (which means legal responsibility of local leaders as demonstrated before). ETS shares the same logic of total load control in terms of emission control but provides more flexible and cost-effective manners for achieving the emissions control target. More capacity building should be done for local governments in order to achieve more cost-effectively their energy- and carbon-intensity targets.

3.3 Possible assignment of ETS and carbon tax

Thus far, **there are no concrete official decisions on which carbon price policy could be assigned to a specific sector**. Likely, a consensus reached so far tells that ETS would be introduced for industry and energy sectors where the installations are limited and carbon tax could probably cover the transport, household and small industrial sectors (author's interview with related stakeholders). For example, ETS could be a useful tool for including major big state-owned enterprises. Such state-owned enterprises communicate more directly and easily with governments thus the ETS would provide them an alternative but more cost-effective way to achieve their energy-saving and carbon-intensity targets assigned by the governments. A good reference could be the 1000 Largest State-owned Enterprises Energy Saving Program which was introduced during the 11th FYP period and which would very probably continue in the 12th FYP period.

4. Implicit carbon price and carbon pricing policy implementation alternatives

This section examines the existing price policies on fossil fuels in China for two purposes. It firstly provides an explicit comparison basis between future carbon pricing policies and the implicit carbon price that the existing price policies generate in order to show the magnitude of the explicit carbon price and discuss whether such explicit carbon price would generate significant marginal effect of reducing the use of fossil fuels. This is a **complementary analysis of the quantitative analysis provided in the previous chapter**. The second purpose of this section is to discuss the possibility and compare the feasibility and (dis)advantages of **introducing a carbon price into current price policies on fossil fuels instead of in the traditional form of CT and ETS.** The reason for doing such an analysis is due to the fact that different views of stakeholders exist on how to introduce a carbon price in China according to author's interviews.

4.1 Existing pricing policies on fossil fuels in China

The implicit carbon price on fossil fuels is generated by different types of policies such as pricing policy, subsidies, etc (for example, Productivity Commission, 2011; Vivideconomics, 2010). This section focuses only on **implicit carbon price generated by current pricing policies on fossil fuels** given that they share the same marginal price mechanism than carbon price. Current policies include taxes such as VAT, resource tax and consumption tax; charges and fees (for example on SO2 and NxO emissions); price regulations on some final oil products, etc. This section shows the implementation incentives and the significance on the price level of fossil fuels of such policies.

4.1.1 Resource tax

In order to fulfill the increasing social demands on natural resources, China has authorized to exploit poor quality resources during the 90s of the last century. By consequence, firms exploiting higher quality resources will receive extra profits from their lower exploiting costs and higher market price (Liu, 2007). In this context, resource tax was initially implemented on January the 1st 1994 for correcting competition disadvantages between exploiting firms rather than its original role of resource conservation. However, as the situation of resource over exploitation aggravated, by the time the *Provisional Regulations on Resource Tax* was promulgated in late 2003, the objective of RT is modified to ensure both the conservation of natural resources and the adjustment of revenue differences on natural resources with different qualities. In fact, due to this double objective, the RT rates which are determined by the State Council vary among regions and mines based on the quality of resource and their exploitation costs (see table 2). The RT was collected jointly by State Administration of Taxation and local taxation administrations and the revenue were shared by central and local governments based on quantities exploited for sale and/or own use (see table 3).

However, as the market prices of certain resources (such as coal, crude oil, etc.) skyrocketed in recent years, this decreased relatively the tax rates of RT which is imposed in specific forms. Reform requesting increasing the level of RT has been submitted to the State Council at the end of 2008 and was however postponed in a time of global economic crisis. As Chinese economy gradually gets rid of the impact of global crisis in 2009, the reform on RT has been revoked: the *Opinions on Strengthening the Economic Reform in 2009* published by China's top regulatory ministry National Development and Reform Commission (NDRC) has clearly pronounced to set resource tax reform plans in an appropriate time. As a result, by June 2010, the test program of RT reform has been launched in Xinjiang Province in China where 5% was given as RT rate on crude oil and natural gas. One major objective of such reform of turning the tax rate basis from real physical quantity to market price is to increase the local government revenue in order to compensate the local environmental and social losses due to resource exploitation. Therefore, tax revenue of RT is totally allocated to local government in recent years.

Table 2. Resource tax rates in China

Item	**Rates**
Crude oil	8-30 Yuan/t
Natural gas	2-15 Yuan/k m3
Coal	0.3-8 Yuan/t
Other non-metal minerals	0.5-20 Yuan/t or m3
Ferrous metal minerals	2-30 Yuan/t
Non-ferrous metal minerals	0.4-30 Yuan/t
Solid salt Liquid salt	10-60 Yuan/t 2-10 Yuan/t

Source: *Provisional Regulations on Resource Tax*, 2003.

Table 3. Current taxation and tax revenue allocation between central and local governments

Tax category	Tax type	Central tax	Local tax	Central/local sharing
Commodities and service	VAT			75%/25%
	Consumption tax	X		
	Sales tax			Various
	Tariffs	X		
Income tax	Firm income tax			60%/40%
	Personal income tax			60%/40%
Resource tax	Resource tax			Various
	City and town land use tax		X	
	Tax on occupation of cultivated land		X	
	Incremental tax on land value		X	
Property tax	Building tax		X	
	Contract tax		X	
	Vehicle and vessel tax		X	
Act tax and others	Urban maintenance and construction tax		X	
	Stamp tax		X	
	Vehicle purchase tax	X		
	Tonnage dues	X		
	Tobacco tax		X	

Source: authors' rearrangement based on related governmental information websites.

4.1.2 Consumption tax

Consumption tax (ConT) was implemented after the publication of *Provisional Regulations on Consumption Tax* in 1994. The objective of ConT is to ameliorate the consumption structure of commodities and orient the consumption. Its revenue belongs uniquely to central budget (see table 3). Interestingly, the implementation respected the fiscal neutrality. Goods taxed by ConT have been granted a lower VAT or product tax level at the time the ConT is implemented and this procedure reinstalled the initial taxation level of these goods. Since then, the consumption tax has been modified by several times both on the rates and involved goods[49]. Nowadays, ConT covers more than a dozen categories of goods, which include final oil products. As table 4 shows, the ConT rates on such fuels remained almost stable

[49] Those circulars include Cai Shui (1998) No.63, Cai Shui (2001) No.84, Cai Shui (2001) No.91, Cai Shui (2001) No.176, Cai Shui (2003) No.86, Cai Shui (2004) No.22, etc.

until 2009 as a result of fuel tax reform mentioned above.

Table 4. Evolution of consumption tax rates on related fossil fuel products in China

Products	Jan. 1, 1994[a]	Apr. 1, 2006[b]	Jan. 1, 2008[c]	Jan. 1, 2009[d]
Unleaded gasoline	0.20yuan/l	0.20yuan/l	0.20yuan/l	1yuan/l
Leaded gasoline	0.28yuan/l	0.28yuan/l	0.28yuan/l	1yuan/l
Diesel	0.1yuan/t	0.1yuan/l	0.1yuan/l	0.8yuan/l
Naphtha	No tax item	0.06yuan/l	0.2yuan/l	1yuan/l
Solvent Naphtha	No tax item	0.06yuan/l	0.2yuan/l	1yuan/l
Lubricating oil	No tax item	0.06yuan/l	0.2yuan/l	1yuan/l
Heating oil	No tax item	0.03yuan/l	0.1yuan/l	0.8yuan/l
Aviation Kerosene	No tax item	0	0	0.8yuan/l

Source: a: *Provisional Regulations on Consumption Tax*, 1994
b: State Notice Cai Shui (2006), No.33.
c: State Notice Cai Shui (2008), No.19.
d: State Notice Guo Fa (2008), No.37.

4.1.3 Fees

Fees (charges) have long been used by both China's central and local governments given its easy administrative procedure relative to taxes. In fact, fees are the first economic instrument of pricing adopted in China for environmental issues: the *Provisional Measures for Collection of Pollutant Discharge Fee* released by the State Council in 1982 clarified the purpose, management and utilization of pollutant discharge fees. This willingness was strengthened by the approval of the *Trial Program for Collection of Pollutant Discharge Fee against SO2 Emission from Industrial Coal Burning* in 1992 which enforced the fees-led environmental management in China (Fang and Zeng, 2007). The *Management Rules of Pollution Discharge Fee Collection Standard* published in February 2003 consolidated fee collection rules by defining clearly calculation methodologies of environmental fees.

Comparing to tax, the implementation of fees is more flexible and administratively simpler in China. First, fees could be implemented by specific central or local institutions and its implementation does not require the creation of new laws. Second, the revenue of fees is usually detained by concerned fee collection institutions and can be redistributed (at least partially) for specific purpose while the revenue of the tax is injected directly into the central or local budget and is not redistributed specifically in China. Finally, the rate of fees can be flexible and discriminative by industrial process and region, while the tax rates must be identical for a same activity.

4.1.4 Oil price regulations

Facing an increasing energy dependency, China began to regulate its domestic final oil products prices based on international oil price fluctuation periodically (Zhao et al., 2010). According to table 5, **the total net price increase due to such a regulation from 2005 to 2010 represents roughly one third of the 2010 market price of the regulated products** such as gasoline, diesel and aviation kerosene. Detailed price regulations can be found in Table A3 of Appendix.

Table 5. Accumulative final oil products nominal prices variation in China 2005-2010 (yuan/t physical quantity of fuel.)

Gasoline	**+3030**
Diesel	**+2760**
Aviation Kerosene	**+2510**

Source: author's rearrangement based on related governmental circulars.

4.2 Implicit carbon price on fossil fuels

In this section, we calculate the implicit carbon price that the above mentioned policies generate. It can be noticed that in a certain extent, almost all policies could engender implicit carbon price as long as they generate (positive or negative) "cost" on the production, transport and consumption of the fossil fuels. However, the choice of policies in this chapter is not total arbitrary given that these policies generate direct cost on the market price of fossil fuels which share the same impact mechanism of carbon pricing policies. In such a term, the implicit carbon price deserves a certain level of comparability with the explicit carbon price that a CT and/or ETS would generate.

We use the following equations to calculate the implicit carbon price that the price policies presented in 3.1 could entail. The proxy is the equalization of the cost that existing policies generate and that an equivalent carbon price could generate. We have

$$\mathrm{Cost_{ij}} = \mathrm{Imp_{ij}} \times \mathrm{CC_j} \qquad (1)$$

where $\mathrm{Cost_{ij}}$ is the unit cost that the ith type of policy generates on the jth type of fuels, $\mathrm{Imp_{ij}}$ is the implicit or equivalent carbon price that the ith type of policy generates on the jth type of fuels that we calculate, $\mathrm{CC_j}$ is the carbon content of jth type of energy. Table 6 lists related data of policy types and market price of fossil fuels. Data of carbon contents and standard coal ratio is given in Chapter Three. As seen, except VAT which is in ad valorem form, other policies all generate specific rates. In order to calculate $\mathrm{Cost_{ij}}$ for different policy cases, we use, with i= VAT policy, resource tax, consumption tax and domestic fuels prices regulation,

$$\mathrm{Cost_{ij}} = \mathrm{p_j VAT_j}/\left(1 + \mathrm{VAT_j}\right) \quad \text{when i=VAT policy and} \qquad (2)$$

$$\mathrm{Cost}_{ij} = \mathrm{T}_{ij} \qquad \text{when } i \neq \text{VAT policy.} \qquad (3)$$

where VAT_j is the VAT rate on the jth fuel and T_{ij} is the specific tax rate of the ith type of policy on the jth fuel.

As we demonstrated above, six major fossil fuels receive price policies. Table 7 enlists the results of implicit carbon price that each policy generates on these fossil fuels. As seen, the final oil products receive much higher implicit carbon prices than primary products principally due to the domestic market price regulation policy. In addition, the consumption tax generates also high implicit carbon prices on such oil products while it is not imposed on primary fossil fuels. For primary fuels, the resource tax generates very low implicit carbon price. As mentioned above, such tax is under reform which aims to increase the tax rates and this could probably increase the implicit carbon price that RT generates in the future. In terms of the marginal effect that an explicit carbon price (CT and/or ETS) could generate, a low start rate at around 10-20yuan/tCO2 could generate higher marginal effect on primary energies, particularly on coal (explicit carbon price accounts for 10-20% of implicit carbon price of coal) than on final oil products in terms of the share of incremental carbon cost to existing implicit carbon costs, other things being equal[50].

[50] Of course, price regulation and price elasticity are key determinants of carbon cost impacts.

Table 6. Related data for implicit carbon price calculation

	Coal	Oil	NG	Gasoline	Diesel	Aviation Kerosene
VAT	17%	17%	17%	17%	17%	17%
Resource tax	0.3-8 Yuan/t	8-30 Yuan/t	2-15 Yuan/km3	0	0	0
Consumption tax	0	0	0	1yuan/l	0.8yuan/l	0.8yuan/l
Fees	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
Domestic market price regulation				+ 3380yuan/t	+ 3110/t	+ 2510/t
Domestic price[51]	1225yuan/t	6312yuan/t	2.2yuan/m3	8990yuan/t	8200yuan/t	5230yuan/t
Volume to weight ratio				1l=0.722 kg physical unit	1l=0.86kg physical unit	1l=0.8kg physical unit

Source: author's arrangement based on related governmental websites and other sources.

Table 7. Results of implicit carbon price on fossil fuels in China (yuan/tCO2)

		Coal	Oil	NG	Gasoline	Diesel	Aviation Kerosene
VAT		90.0	299.1	146.4	436.9	377	254.2
RT	Low level	0.15	2.61	0.92	0	0	0
	High level	4.05	9.78	6.88	0	0	0
ConT		0	0	0	242.3	217.7	214.8
Fees		N/A	N/A	N/A	N/A	N/A	N/A
Fuel price adjustment		0	0	0	1134.2	984.2	842.3
Total		**94.05**	**308.88**	**153.28**	**1813.4**	**1578.9**	**1311.3**

[51] Domestic market prices of these fuels fluctuate dramatically by period and their levels here are in fact a very vague average based on information of several sources. Therefore, the implicit carbon price that VAT policy engenders might vary according to the market price chosen. The sources of the market prices of these fossil fuels include business reports from: http://www.sxcoal.com/coal/1802150/articlenew.html; http://news.sina.com.cn/z/bjtrqjg/index.shtml; http://www.52oil.com/article/show.php?itemid=410677 and http://www.chemcp.com/news/201105/191419.asp (all in Chinese).

4.3 Alternatives of introducing carbon price

Besides the direct implementation of carbon pricing policies, there are also several alternatives of introducing a carbon price based on existing policies mentioned above. The general advantage of such indirect carbon price introduction is the shorter administrative procedures than direct implementation of carbon pricing policy. However, the general disadvantage of the indirect carbon price introduction is the lack of explicit carbon price and thus the lack of comprehensibility. This section shows advantages and shortages of different indirect carbon cost introduction possibility.

4.3.1 Integration of carbon cost into RT

The common advantage of integrating the carbon cost into the existing taxes is the relatively shorter and easier administrative procedures required. Therefore, an alternative implementation of carbon price is to increase explicit carbon cost in RT on coal, crude oil and natural gases. Such form could cover all CO2 emissions from fossil fuel combustion since primary energies are taxed. Plus, as long as RT rate remains in the form of specific duty, this facilitates the integration of carbon cost (which is also in specific form) comparing to other ad valorem taxes.

However, such integration would also tax primary resources which are consumed for non energy use (for example, crude oil for plastic production) despite the fact that such part of primary resources might be small. In such a case, an exemption of carbon cost imposed on primary fossil fuels for non energy use could be made. Also, such introduction of carbon cost will not concern the import of final fossil fuels (gasoline, kerosene, etc.). This would require extra import CP measures by whether integrate the carbon price into the import tariffs or imposing direct import carbon tax. Moreover, given that the reform of RT which aims to turn the specific duty to ad valorem tax has been launched with a major purpose of increasing local government revenue beside resource reservation, the introduction of a carbon cost would generate additive administrative complexities, particularly on the use of the revenue that the carbon price generates through RT.

4.3.2 Integration of CP into ConT

During the 2006 ConT reform, the role of consumption tax for protecting environment has been strengthened. The reform has discriminated cars by engine displacements and flow rates and increased dramatically levies on lumber floors and chopsticks in order to reflect consumer environmental responsibility. In such a context, a carbon price could be integrated into the consumption tax for addressing climate change. Given the specific form of ConT rate, carbon cost could be comprehensively included. However, this would require creating new tax category of other final fossil fuel consumptions such as coal and natural gas. An alternative solution is therefore to introduce carbon price both into the coal and natural gas under RT and oil products under ConT.

4.3.3 Carbon fees

Given its administrative facility of implementation relative to taxes, the carbon fee could therefore be introduced more rapidly. Local collection entities (for example, local taxation administrations which are now in charge of the collection of wasted water emissions fees) could be assigned to collect carbon fees and its revenue could be redistributed to specific use on climate friendly activities. However, one inconvenience of such method is that it goes against the general reform in China which aims to replace fees by taxes, thus reducing the long-term viability of such carbon fees.

5. Key issues toward a successful implementation of carbon pricing policies

We have demonstrated above that the implementation of a carbon price still encounters different uncertainties and barriers of implementation. In this section, we discuss some fundamental elements which could ensure and accelerate the implementation and a good functioning of carbon pricing policy in China.

5.1 Coordination

The coordination issue constitutes an important component for a successful introduction of the carbon price. Both interministerial and central-local government coordination would be treated in China.

5.1.1 Inter-ministerial coordination

Given the intertwined functions among ministries on climate change related issues (Yu, 2010), the State Council has decided to play its role of coordinator in 2007. The *State Council Notice of Establishing the* ***Working Group of Climate Change and Energy Conservation and Emissions Reduction***[52] published at that time (here below named "Group") has thus founded a way of facilitating inter-ministerial coordination on dealing with energy and climate change issues. The Group assembles ministers from 17 ministries and is chaired by China's Premier, WEN Jiabao. Its major functions include

- the research and making of national climate change strategies, plans and policies;
- deploying adaptation works; revising and authorizing international cooperation and negotiation plans;
- coordinate major questions/obstacles of climate change;
- implement related policies of the State Council of energy conservation and emissions reduction;
- deployment of related energy conservation and emissions reduction works;
- examine and authorize major energy conservation and emissions reduction policies and coordinate related works among ministries.

Carbon pricing policy would need to be well coordinated by the Group which defines clearly functions among major ministries concerned. Currently, the NDRC is

[52] Guo Fa (2007) No.18 of the State Council.

responsible of leading the climate policies making process. It is also in charge of related international cooperation/negotiations together with Ministry of Foreign Affairs. Comparing to other ministries, the NDRC has a relative political importance by its function of macroeconomic planning, which can be better seen from its former title, National Development and Planning Commission. In addition, the minister (chairman) of NDRC is usually promoted to higher positions in the State Council after their mandate at NDRC, comparing to other ministers or province leaders who usually change their positions at the same administrative level. This could indicate a higher administrative weight of NDRC relative to other ministries.

Taken account that the start level of the carbon price would probably be low principally due to consensus reached among mainstream studies and proposals, **the implementation of carbon pricing policy** (whether in the form of ETS or a carbon tax) **might rather be domestic concerns than for international cooperation for the time being**. However, carbon price would become an international issue when more stringent efforts are needed in China whose global responsibility of climate change increases. NDRC could be granted the leading role of determining and modifying carbon pricing policies together with other ministries while leading the international negotiation concerning carbon pricing policies together with Ministry of Foreign Affairs. Ministry of Finance and State Administration of Taxation could play the tax collection and (re)distribution functions if a carbon tax is implemented.

In terms of CO_2 emissions inspection, the function definition is not clear among ministries in China. Ministry of Environmental Protection, which is so far not a central climate policy decisive institution in China, might take the role of the control, inspection and verification of fossil fuels combustion of each firm, and eventually together with local taxation administrations on controlling firm accountings related to fossil fuels. The Ministry of Environmental Protection being in charge of the control of SO_2 and COD emissions which are mandatory targets of emission reduction during the 11th FYP (2006-2010) and 12th FYP (2011-2015), and NDRC which conducted energy (saving) audits, could therefore assure the inspection of CO_2 emissions given their similar administrative requirements to SO_2, COD emissions and energy consumption auditing.

5.1.2 Central local government coordination

In terms of central local government administrative coordination, the above mentioned coordination Group of the State Council does not include local province leaders. The participation of local chiefs to the Group would strengthen central local dialogues of climate policy, thus facilitating the implementation of CT as well as other climate policies. In terms of tax revenue sharing, under the current reform of fee-to-tax mentioned above, local governments' fiscal revenue from fees which would be replaced by taxes begins to contract. Therefore, **the carbon pricing policy could consider a central-local government share of revenues that a carbon tax and/or ETS might engender.** This share of central-local government revenue could vary given different local provinces in terms of their vulnerability to climate change as well as other needs of climate change activities. For example, it could be necessary to allocate more revenues that a carbon pricing policy could engender to regions which are more vulnerable to climate change and where the economic development falls behind national average.

5.2 Revenue redistribution

The revenue redistribution is one of the most important elements that ensure the positive welfare effect that a carbon pricing policy could generate. As have studied in Chapter Four, a good use of specific revenue redistribution could generate total welfare increase. Therefore, the design of the use of any revenue raised from carbon pricing policies should be simultaneous to the implementation of such policy itself. This section examines the **feasibility of a specific use of revenues** that the carbon pricing policy would generate under the Chinese context.

5.2.1 Current specific revenue redistribution policies in China

In China, there is so far no specific use of tax revenue where the central/local government redistributes total tax revenue. However, certain funds which are currently collected by taxation administrations dedicate to non-fiscal use. Their revenue is redistributed to related specific activities to which the specific function of carbon price revenue can refer. Three funds may be examined.

First, the **extra charges of education fund** were implemented in 1986 pursuant to the promulgation of *Provisional Regulation of the imposition of Extra Charges of Education Fund* by the State Council. Such charges are collected by central and local taxation administrations as defined by the *Law of Education* (approved in 1995). A rigid tax rate of 3% is collected on the amount of the total VAT, ConT or transaction tax that each firm pays. The revenue of such charges is totally granted to China's educational entities with the major objective aiming to promote free education.

Second, the **mining royalty** was introduced in 1989 after the publication of the *Provisional Regulation of the Imposition of Mining Royalty on Offshore Petroleum Resources Exploitation* and *Provisional Regulation of Mining Royalty on Sino-foreign Cooperative Exploitation of Inland Petroleum Resources*. Such regulations set progressive tax rates (2-12.5% for crude oil and 1-3% for natural gas) based on the production amount of crude oil exploitation firms. The general use of the revenue is to support international cooperation on oil exploration in China.

Third, the **charge for cultural construction** was implemented in 1997 by the State Council. The *Provisional Regulation of the Imposition and the Management of the Special Fund for Cultural Construction* enables local taxation administrations to collect 3% from firms based on the amount of the transaction tax of entertainment and advertisement activities that related firms pay. The revenue is redistributed totally to special funds of central and local governments for improving cultural construction.

5.2.2 Possible implementation of a carbon fund

The common character of the above-mentioned funds is that the tax/charge rate is fixed by the State Council while central and local taxation administrations are only in charge of tax collection and distribution to related funds which redistribute tax revenue for specific purposes. The **creation of a carbon fund** may follow this structure which could allow the specific revenue redistribution if a carbon tax and/or ETS is implemented. Both central and local carbon funds might be necessary according to different political and economic needs. Two options could be considered for the implementation of a carbon fund. First, it could be independently established. Second, it could merge with the Clean Development Mechanism (CDM) Fund of China which was approved to be established by the State Council in 2006. This fund is considered to be an innovative mechanism making specific uses of revenues raised from CERs (Certificated Emission Reduction) transactions on climate change related activities. The Carbon Fund could be jointly supervised by NDRC and MOF, while being granted independent operation rights similar to CDM Fund. Local institutes could therefore supervise the operation and the use of local carbon funds.

The use of the revenue generated by carbon pricing policies can also be various. Generally, it can be used to develop climate-friendly activities and technologies. Such revenue could also be given to banks and be transformed into the financial pool for low- or zero rate loans for green investments. Finally, as 5.1.2 mentioned, the revenue could also be used to compensate economic and social impacts for poor regions where the enclosure of small and efficient installations might generate higher economic and social impacts.

6. Conclusion

We have demonstrated in this chapter three fundamental issues. First, the implementation of a carbon price policy whether in the form of a carbon tax or emission trading system still encounters many uncertainties (such as legislation barriers, forms of carbon price, etc.) and would require strong coordination work in order to ensure a good and effective functioning. As table 6 shows, by comparing different determinants discussed in sections 2 and 3, in terms of the level of feasibility, there is so far no optimal options of the implementation of a carbon price in China. Second, although the implementation of ETS has been officially announced, **the carbon price level would be low in short-term and would be very difficult to reach to an internationally comparable level by the end of the 12th FYP period (2011-2015)**. This is due to two major determinants. First, the consensus reached by major proposals and studies on the rate of the carbon price has favored a low start carbon price. Second, the implementation agenda of ETS which aims to implement a national wide ETS no earlier than 2016 would probably not generate a high carbon price before that time. Finally, current pricing policies such as taxes and price regulation on fossil fuels in China already generate a very high level implicit carbon prices (roughly 10-200 euro/t CO_2) where the domestic price regulation on final oil products is the major contributor. The latter links domestic final oil products prices to international oil price and can sometimes generate an ineligibles price fluctuation. If such price increase can be considered “acceptable”, a high carbon price could also be considered feasible.

In order to accelerate the implementation of domestic carbon price policy, this chapter has therefore assessed several key determinant issues and recommended **three major proposals**:

- To consolidate coordination work both at interministerial and central-local level and to introduce central government-interministerial-local government coordination led by the State Council.
- To establish a special carbon fund in order to guarantee specific revenue redistribution. This fund could also play the function of compensating the negative competitiveness impacts of sectors of the least developed regions.
- To (re)examine the coverage of carbon pricing policies in order to design proper forms of carbon pricing policies for different sectors in order to reduce management costs.

Finally, there are some further issues which have not been elaborated in this chapter:

First, this chapter did not discuss the fiscal neutrality. This could be achieved by a reduction of labor tax or the transaction tax to release the operational charges of the firm under the context of increasing operational costs in China. However, as has been shown above in the case of ConT and RS, the introduction of a new tax or a tax rate increase did not respect fiscal neutrality, which may lead to further subject of research on the fiscal neutrality issue under Chinese fiscal context.

Second, the proposal of implementing energy tax (ET) has long been debated during the 90s of the last century. Given the implementation history of fuel tax mentioned above, the implementation of a “complete” ET still remains immature. In fact, energy tax competes with carbon pricing policies in China given their similar effects and functions in terms of implementation. Concerning their economic impact and administrative efforts required, the implementation of the one would very probably disable the short-term implementation of the other. If the carbon pricing policy is considered being able to engender similar effects of energy conservation of ET, its implementation could take the advantage of related works on the implementation of ET. Given that such works were effectuated earlier than those for CP policies, this could shorten the administrative procedures of the implementation of CP.

Finally, certain energy-intensive industries still receive reduced energy price and/or subsidies from governments in China. Although the general willingness lays on the suppression of such subsidies, the achievement would be progressive. If such anomalies of energy subsidies could not be removed, the credibility of reducing GHG of a country might be questioned. Therefore, the implementation of carbon pricing policies should also contribute to accelerating the suppression or major reduction of the use of energy subsidies.

Table 6. Comparison among implementation options of a carbon price

	Direct Implementation	CP in RT	CP in ConT	Carbon fees
Administrative process requirement and uncertainty	High	Medium	Medium	Low
Comprehensibility	High	Medium if RT is in specific tax; Low if RT is in ad valorem rate	Medium	Medium
Long-term predictability	High	Medium	Medium	Low
Domestic coordination	Easy	Low	Low	Low
International coordination	Easy	Low	Low	Low

Note: The levels here are purely indicative based on the author’s analysis.

References[53]:

Chang, Y.-C., Wang, N., 2010. Environmental regulations and emissions trading in China, E*nergy Policy* 38, pp.3356-3364.

Cong, R.G., Wei, Y.M., 2010. Potential impact of (CET) carbon emissions trading on China's power sector: A perspective from different allowance allocation options, *Energy Policy* 35, pp.3921-3931.

Ekins, P., Barker, T., 2002. Carbon taxes and carbon emissions trading, in Hanley, N., Roberts, C., Eds., *Issues in Environmental Economics*, Blackwell Publishing, pp.75-126.

Ellerman, A.D., Convery, F.K., de Perthuis, C., 2010. *Pricing Carbon. The European Union Emissions Trading Scheme*, Cambridge University Press.

Hu, M., 2009. The exploration of implementation of emissions trading system in China, *Journal of Service Science and Management* 2009(2), pp. 270-275.

Jiang, K.J., Hu, X.L., Deng, Y.Y., Zhuang, X., Liu, H., Liu, Q., Zhu, S.L., 2009. Impact of carbon tax and analysis on related issues, in: Hu, X.L., Wang, J.Z., Cen, L.Y., Lei, H.P. (Eds), 2050 China Energy and CO_2 Emissions Report. Science Press, Beijing, pp. 413-445. (in Chinese)

Kaplow, L., Shavell, S., 2002. On the superiority of corrective taxes to quantity regulation, *American Law and Economics Review* 4, pp.1-17.

Liu, Z., 2007. *China Taxation*, Economic Science Press, Beijing.

Productivity Commission, 2011. Carbon emission policies in key economies, *Productivity Commission Research Report*, Australian Government.

Su, M., Fu, Z.H., Xu, W., Wang, Z.G., Li, X., Liang, Q., 2009. A research on the implementation of carbon tax in China, Review of Economic Research 72, pp.2-16. (in Chinese)

Tietenberg, T.H., 2006. *Emissions Trading. Principles and Practices*, 2nd Ed., Resources for the Future, Washington, DC.

Vivideconomics, 2010. The implicit price of carbon in the electricity sector of six major economies, *Vivideconomics Report* prepared for the Climate Institute, 2010.

Wang, J.N., Yang, G., Jiang, K.J., Liu, L.C., Yang, J.T., Ge, C.Z., 2009. The study on China's carbon tax policy to mitigate climate change, *China Environmental Science* 2009(29-1), pp.101-105. (in Chinese)

Wang, X., Zhang, Y., 2010. Difficulties in carbon price making and solutions, *Theoretical Exploration* 2010(03), pp.66-69. (in Chinese)

Wang, Y., Pan, S., 2009. Status and trends of China carbon market under financial crisis, *Economic Theory and Business Management* 2009(11), pp.19-24. (in Chinese)

Weitzman, M.L., 1974. Prices vs quantities, *Review of Economic Studies* 41, pp.477-491.

Yang, Z., Chen, B., 2010. Regional emission trading in China, *Academic Monthly* 494, pp.44-47. (in Chinese)

Ye, R., von Weizsacker, E.U., 2009. Economic instrument for energy efficiency and the environment, *China Council for International Cooperation on Environment and Development (CCICED) Policy Research Report*, Beijing, 2009.

Yu, T., Zhang, X., Ma, Y., 2010. Strategies of establishing carbon trading in China, *Social Science Journal* 2010(02), pp.90-94. (in Chinese)

Yu, X., 2010. An overview of legislative and institutional approaches to China's energy development, *Energy Policy* 38, pp.2161-2167.

[53] Including citations in Appendix.

Zhang, Z.X., Baranzini, A., 2004. What do we know about carbon tax? An inquiry into their impacts on competitiveness and distribution of income, *Energy Policy*, 32, pp.507-518.

Zhao, X., Ma, C., Hong, D., 2010. Why did China's energy intensity increase during 1998-2006 : decomposition and policy analysis, *Energy Policy* 38, pp.1379-1388.

Zhou, N., Levine, M.D., Price, L., 2010. Overview of current energy-efficiency policies in China, *Energy Policy* 38, pp. 6439-6452.

Appendix A. Related tables of the chapter

Table A1. Implementation history of fuel tax in China, 1997-2009.

Date	Related person/institution	Actions
1997	Road Law approved by the Congress	Replace road maintenance fee by fuel surcharge (fee), to be implemented from Jan. 1, 1998.
Oct. 1998	Fuel tax reexamined by the meeting of standing members of the Congress; State Council submitted the revision of Road Law to the Congress	Revision of Road Law disapproved by the Congress; related discussions on fuel tax were postponed.
Oct. 31, 1999	Revision of Road Law approved by the Congress	Fuel surcharge is replaced by fuel tax officially.
Nov. 4, 1999	Officials of Ministry of Finance	Pronounced that the Revision of Road Law had cleared all obstacles for implementing fuel tax. Fuel tax plan has been already submitted to the State Council and would be implemented recently.
Jan. 4, 2001	JIN Renqing (Minister of the General Administration of Taxation at the time)	Pronounced that the implementation process of fuel tax was complete. Fuel tax would be implemented during the second semester of 2001.
2002	idem	Pronounced that fuel tax would be implemented at a more appropriate time.
Mar. 2004	XIE Xuren (Minister of the General Administration of Taxation at the time)	Pronounced that the fuel tax was under final administrative approval procedure and would be implemented at an appropriate time.
2006	JIN Renqing (Minister of MOF at the time)	Pronounced that related receipts had already been printed and the fuel tax would be implemented soon.
Jul. 26, 2006	NDRC at the national meeting of energy saving	Stated the necessity of tracking the international oil price changes and ameliorating the fuel tax plan for a rapid implementation.
Jul. 26, 2006	LIAO Xiaojun (vice-minister of MOF at the time)	Pronounced that related departments of MOF were working

		on the finalization of fuel tax plan.
Dec. 2006	JIN Renqing (Minister of MOF at the time) at national meeting for fiscal issues	Pronounced to strengthen the finalization of fuel tax plan in 2007 and implement it at an appropriate time.
Jan. 2007	SAT	Published "Key working areas of 2007" which included the implementation of fuel tax.
Sept. 13, 2007	Official of SAT	Pronounced that China would implement fuel tax to replace road maintenance fee.
Oct. 15, 2007	RAO Da (Secretary General of National Association of vehicle information)	Pronounced that the fuel tax plan was already mature. As part of central objects of the government, it would be implemented no later than March 2008.
Dec. 5, 2008	Notice of NDRC and MOF	Draft version: increase consumption tax rates of gasoline and diesel and abolish road maintenance fee and other related fees.
Dec. 18, 2008	Circular of the State Council	Official implementation of product oil tax since Jan. 1, 2009.

Source: authors' rearrangement based on related official releases and journals.

A2. Details of researches and proposals on CT and ETS in China

Subject	Authors/teams	Contents
CT,2010	SU et al. (MOF)	Leading group promoting CT to Government. The most detailed qualitative studies so far: Exemption on household use of coal and NG. Several options to introduce CT (separately, with resource tax reform, with environmental tax reform; the reforms of such taxes should level tax space for CT) Possible differentiated rates; industrial competitiveness concerns On production/consumption Based on estimated/real CO2 emissions Time suggested: 2012-2013
CT,2009	JIANG etal. (ERI, NDRC)	Quantitative, horizon 2050, IPAC-AIM model. CT or CT with energy tax jointly. Energy price effect important. But the model did not consider the contribution of the import decrease, and, the deductive effect of energy sector investment to the increase of clean sector

		investment. The use of CT for being exempted by BTA is pronounced.
CT, 2009	Fan[54]	Use of CT for BTA.
CT, 2009	YE (MEP) and Weizsaker	CCICED taskforce report. For EE, also anti-BTA. CT as part of env. tax (SO2, wasted water, COD) Latest implementation before 2020. CT, is not affected by “fees to tax” reform.
CT,2009	WANG et al. (MEP)	Specific use of tax revenue. CT funds.
ETS,2011	ZHANG Jianhua[55] (Central Bank)	Carbon intensity target will require more than 100 million yuan each year, cannot be afforded by fiscal budgets alone. ETS can help. ETS, first step could include 6 most EI sectors.
ETS,2010	YU et al.	ETS to set game rules/standards favorable for Dping countries Financial derivatives are important.
ETS,2010	WANG and Zhao	ETS: cf. price floor of CERs (8 euro/t), not efficient when EU ETS price is low (7euro/t Feb 2009). ETS: improve mobility of CERs. ETS: help to increase the importance of China in world financial market
ETS,2009	WANG and Pan	CO2 quota price will be higher when China has to reduce its absolute CO2 emissions. ETS may play a role of quotas conservation.
ETS,2010	YANG and Chen	ETS, China could become price maker on CERs. Cf. the lesson in crude oil world market.

Note: authors are academic if their institution not indicated.
Note: References are given in the References of this chapter.

Table A3. Details of oil products prices regulation in China: 2005-2011

Date	Concerned products	Actions (yuan/t oil products)
Feb. 20, 2011	Gasoline Diesel	+350 +350
Dec. 22, 2010	Gasoline Diesel	+310 +300
Oct. 26, 2010	Gasoline Diesel	+230 +220
Jun. 1, 2010	Gasoline Diesel	-230 -220

54 See “Carbon tax vs carbon border tax“ available at http://finance.ifeng.com/opinion/zjgc/20090909/1212478.shtml
55 Available at http://www.cnr.cn/newscenter/gnxw/201101/t20110108_507562013.html

Apr. 14, 2010	Gasoline Diesel	+320 +320
Nov. 10, 2009	Gasoline Diesel	+480 +480
Sept. 30, 2009	Gasoline Diesel	-190 -190
Sept. 2, 2009	Gasoline Diesel	+300 +300
Jul. 28, 2009	Gasoline Diesel	-220 -220
Jun. 30, 2009	Gasoline Diesel	+600 +600
Jun. 1, 2009	Gasoline Diesel	+400 +400
Mar. 25, 2009	Gasoline Diesel	+290 +180
Jan. 15, 2009	Gasoline Diesel	-140 -160
Dec. 19, 2008	Gasoline Diesel	-900 -1100
Jun. 20, 2008	Gasoline Diesel Aviation Kerosene	+1000 +1000 +1500
Nov. 1, 2007	Gasoline Diesel Aviation Kerosene	+500 +500 +500
Jan. 14, 2007	Gasoline Aviation Kerosene	-220 -90
Mar. 26, 2006	Gasoline Diesel Aviation Kerosene	+300 +200 +300
Jul. 23, 2005	Gasoline Diesel Aviation Kerosene	+200 +150 +300
Total variation (nominal price)	**Gasoline** **Diesel** **Aviation Kerosene**	**+3380** **+3110** **+2510**

Source: author's arrangement based on related official notices.

Chapter Five. Export restrictive policies on energy-intensive products in China[56]

1. Introduction

We have demonstrated in Chapter Four that there exist uncertainties for implementing a national wide carbon price in the short term and that a comparable carbon price could come even later in China. A low start carbon price can no doubt contribute to domestic development of China but could neither theoretically nor politically lessen the competitiveness and carbon leakage problems in Annex I countries, particularly the EU where an emission trading system has been established. As a result, there would always be competitiveness and carbon leakage arguments which can slow down the implementation of more stringent climate policies in the EU.

Among current Chinese policies, export VAT refund rebate and export tax (EVRRET) policies are market-based instrument and have been massively introduced on energy-intensive products since 2007. Both positive and negative points rise from EVRRET in the framework of tackling climate change. The positive point comes from the fact that EVRRET are initially implemented for environmental concern and have also been officially declared as climate policy. However, the negative point declares that such policy lacks in explicit, stable and predictable carbon price signal. This makes **EVRRET not a comprehensive climate measure both for domestic exporting industries**, particularly in the context of developing the low carbon economy (LCE) **and for the world**, particularly in the context of competitiveness and carbon leakage.

There exist a general literature on China's export and its GDP growth (for example, He and Zhang, 2010) and some studies focusing on the contribution of export to China's energy intensity. For example, Zheng et al. (2011) show that greater exports aggravate energy intensity of the industrial sector in China. Kahrl and Roland-Holst (2007) demonstrate that export constitute the largest source of energy demand growth in China. However, few studies have focused on disentangling EVRRET in China. This chapter aims to demonstrate in a detailed manner both the **policy willingness and the lack of comprehensive carbon price signal of EVRRET** which provide an important basis for assessing the introduction of an explicit carbon price on China's export in the last two following chapters. This chapter is organized as follows: Part Two reviews the use of export tax policies in a global context and demonstrates the objective(s) of China's EVRRET policies; Part Three shows the policy

[56] Chapter Five, Six and Seven contain two papers under review:
Wang, X., Li, J.F., Zhang, Y.X., A case for introducing an explicit carbon price into China's export, under review at ***Climate Policy***.
Li, J.F., Wang, X., Zhang, Y.X., Is it in China's interest to implement an export carbon tax?, under review at ***Energy Economics***.

willingness of EVRRET of China and then demonstrates the policy instability of EVRRET; Part Four calculates the implicit carbon price that EVRRET generate both at product and sectoral level; Part Five concludes.

2. Incentives of using export restrictive policies

Export restrictive policies include export VAT refund rebate and/or suppression, export tax (usually in cases of zero export VAT refund or the absence of VAT or refund system), export quotas, licenses and export bans. So far, EVRRET are principal measures adopted among export restrictive policies in China. This section explores the incentive(s) of using EVRRET policies in China with a comparison with international experiences of using export tax policy and demonstrates the intertwined objectives (environment and economic) of EVRRET.

2.1 Export VAT refund and its rebate

2.1.1 Policy evolution and major incentives

China's export VAT refund rate has experienced wide variations since a system of partial reimbursement of the 17% domestic VAT was established in 1985. Export VAT refund rates were originally used for three categories: on coal and agriculture products with a lower refund rate ranging between 3-7%, on industrial products with rates ranging between 10-13% and on other products with rates ranging from 14% to a total export VAT refund rate of 17%. As export began to account an important share of national economy, export VAT refund adjustments are introduced more frequently based on different incentives in recent years, those incentives include:

- Conform to fiscal reform
- To increase government revenue
- To promote and/or stimulate export
- To reduce trade disputes
- To protect environment and non-renewable resources
- To contribute to achieving domestic energy efficiency targets

As table 1 summarizes, China has introduced several export VAT refund adjustment since 1994. In 1994 a new fiscal system was adopted, providing a full refund of VAT on exported products. However, this arrangement did not last long. Full refunding imposed a heavy burden on the central budget, leading to subsequent cuts in VAT refund rates, set to 3%, 6% and 9% during 1995 and 1996. Then, following the 1998 Asian financial crisis, rates were adjusted upwards to cope with losses in competitiveness caused by an overvalued exchange rate. By July 1999, VAT on China's major exports (clothing, electronic equipment, transport equipment and machinery, etc.) was fully refunded while VAT refund rates were raised to 5%, 13% and 15% for other products. Between 1999 and 2002, China's exports experienced an unprecedented increase, triggering a huge amount of VAT refunding which in turn translated into a financial burden for the central government. In 2003, a joint statement by the Ministry of Finance and State Administration of Taxation regrouped the export VAT refund rates at 5%, 8%, 11%, 13% and 17% levels for 2004 (Cai Shui

(2003) No.222).

2.1.2 Policy orientation in recent years

The most controversial modification of export VAT refund rates took place at the time where environmental issues began to have their importance in the new century. The idea of curbing energy intensive exports by means of trade policy was frequently debated during China's tenth Five Year Plan (2001-2005) when energy and environmental problems were given a high profile and became "official issues". Thereafter, the 11th FYP (2006-2010) has clearly required limiting such products' export, pursuant to a circular published by seven ministries (Fa Gai Jing Mao (2005) No. 2595). A series of export VAT rebates took place after such announcement: in September 2006, VAT refunding was abolished for several natural resources and primary products; and reduced for a number of highly polluting and energy consuming products. At the same time, VAT refunding was increased for those commodities deemed to have a high value added or a high technological content. The official objective appeared clearly: **to shift China's export structure towards more value-added and high technology products and away from those that cause pollution and consume large amounts of (natural) resources**, as were emphasized by the 11th FYP and the 12th FYP.

A good example of using EVRRET for environmental protection as well as energy saving concerns can be found in China's energy intensity (EI) target, which aims to reduce EI by 20% by the end of 2010 compared to the 2005 level. Under circumstances aggravated by an energy intensity increase of 3.2% and 0.09% respectively in the first trimester and semester of 2010, which made achieving the total energy intensity target more difficult than ever, China cancelled the export VAT refund for 406 energy-intensive products on 15 July 2010 (circular Cai Shui (2010) No. 57).

The using export VAT refund rebate the energy- and resource-intensive products was also incorporated by China's general reform after joining the WTO. Following WTO accession, China's booming trade surplus has continuously fueled disputes with its trade partners. On 19 June 2007, in an attempt to demonstrate China's good faith by making efforts to keep trade surplus under control, the Ministry of Finance (MOF) and the State Administration of Taxation (SAT) jointly issued Circular No. 90 (which became effective on 1 July 2007) which profoundly modified the VAT refunding scheme on exports. It reduced VAT refund rates for 2,831 commodities, accounting for 37% of China's tariff codes. As a result, VAT refund rates were reduced by between 2 to 8 percentage points on 2,268 commodities deemed likely to trigger trade disputes. Noticeably, the 2007 cuts to VAT refund rates continued to focus on eliminating rebates on 552 goods that produce high amounts of pollution and consume excessive amounts of energy.

However, the firmness of curbing energy-intensive products export has been partially compromised by the global economic crisis. In the wake of the 2008 financial crisis, export VAT refund rates were raised on thousands of commodities (HS 10-digit), mostly labor-intensive, high value-added and high technology products. Such major increase of export VAT refund rates on final products also included some steel products and other final products of the energy-intensive products category, despite the fact that the export refund for most energy-intensive products still remained low relative to other products. In general, the export VAT refund increase took place for several times during 2008 and 2009 after the release of Cai Shui (2008) No.111, No. 144, No.177 and Cai Shui (2009) No.14, No.43, No.88.

Table 1. Major export VAT refund adjustments in China: 1994-2010 (domestic VAT: 17%)

Period	Contents	Major incentives
1994	Full export VAT refund	Fiscal reform
1995-1996	Partial export VAT refund with refund rates at 3%, 6% and 9%.	Government revenue
1998-1999	Increase of export VAT refund rates due to Asian financial crisis. Specific refund rates are 5%, 8%, 11%, 13%, 15% and 17%.	Stimulate export
2004	Regroup export VAT refund rates into the category of 5%, 8%, 11%, 13% and 17%.	Government revenue
2005-2007	Decrease or withdraw export VAT refund rates for energy-intensive products and products triggering trade dispute; increase the export VAT refund rates for products with higher value-added and technology contents (such as equipments, bio-technology and information technology, etc.)	Environment protection; promote export; reduce trade disputes
2008-2009	Increase export VAT refund rates for manufactures (including some downstream energy-intensive products such as steel sticks/products) due to global crisis.	Stimulate export
2010	Withdraw export VAT refund for 406 energy-intensive products due to the difficulty of achieving the energy intensity target (which aims to reduce 20% energy intensity by 2010 with regard to 2005).	Environmental protection; contribution to achieving domestic energy/climate targets.

Source: author's arrangement based on governmental information of related circulars and notices from official websites of Ministry of Finance, State Administration of Taxation, General Administration of Customs and Chinese Central Government Portal (www.gov.cn).

2.1.3 Current structure of export VAT refund

Table two shows the differentiation of export VAT refund rates on different products of total Chinese export in 2010 which is representative enough for a general export VAT refund structure of recent years in China. As seen, most of energy-intensive products (marked in grey in table two) such as metals, chemical and non-metallic products receive low and/or zero export VAT refund yet most of the products with higher value-added and/or longer process chains receive high and/or full export VAT refund rates (such as machinery and equipments). **By creating a cost differentiation, Chinese export VAT refund policy favors the export of products with higher added value and technology contents.** This indicates and confirms that the general strategy of export in China is to restructure the export toward larger contents of products with higher value-added and more advanced technology and fewer components of energy-intensive, polluting and resource-extracting products, despite the fact that export VAT refund increase has been used to increase the export of certain energy-intensive products during the period of economic crisis.

Table 2. Export VAT refund rates and corresponding product numbers (HS-10) in 2010

	Low rate		Medium rate		High rate				
Sectors	**0%**	**5%**	**9%**	**13%**	**15%**	**16%**	**17%**	**Tot prod(HS-8)**	**Related HS codes (HS-2)**
Agriculture	299	868	0	159	444	0	0	**1770**	HS01-24
Mineral product	231	0	0	5	0	0	0	**236**	HS25-27
Chemical product	518	157	1798	327	158	0	11	**2969**	HS28-38
Plastic & Rubber	5	104	95	129	0	0	0	**333**	HS39-40
Skins & Leather	137	9	0	17	20	0	0	**183**	HS41-43
Pulp & Paper	113	3	0	75	0	0	0	**191**	HS47-49
Textiles	21	33	0	27	6	3320	0	**3407**	HS50-63
Plaster, Cement, etc.	23	97	21	68	0	0	0	**209**	HS68-70
Iron & Steel	75	6	77	54	0	0	0	**212**	HS72
Steel products	0	63	72	30	0	0	0	**165**	HS73
Aluminium	18	0	0	37	6	0	0	**61**	HS76
Other base metals	118	76	15	30	0	0	1	**240**	HS74,75,77-81
Tools of base metal	0	59	57	23	0	0	0	**139**	HS82,83
Wood product	243	24	62	41	0	0	0	**370**	HS44-46
Footwear, etc.	2	0	0	0	95	0	0	**97**	HS64-67
Pearl, precious metals, etc.	66	59	3	0	0	0	0	**128**	HS71
Machinery	11	0	0	123	542	0	1198	**1874**	HS84,85
Transport equipment	4	0	0	17	114	0	367	**502**	HS86-89
Optical, music instruments	27	0	0	109	200	0	111	**447**	HS90-92
Arms	22	0	0	14	0	0	0	**36**	HS93
Other manufactured articles	24	0	0	126	55	8	0	**213**	HS94-96
Arts and others	20	0	0	3	0	0	0	**23**	HS97,98

Source: Authors' rearrangement based on data of the State Administration of Taxation of China.

2.2 Export tax

Export tax is a similar instrument of export VAT refund rebates in terms that both generate cost on export. In theory, the impact of export tax is significant in the short term for "large" countries whose export account a big share of world export (Karapinar, 2010). For a small country facing inelastic world demand, the use of export tax will reduce its export to zero, thus domestic producers will bare the cost of export tax. In the long term, both demand and supply become more elastic. Therefore, neither the domestic producer nor the foreign consumer will bear the cost of an export tax in the long run. The cost of the export tax will be borne by those actors of production specific to the production of the taxed good that cannot move to another sector (Piermartini, 2004).

However, despite the fact that the effectiveness of export tax still receive limits under concerns of long-run demand and supply elasticity, competing goods that are substitutes on the world market, oligopolistic market structure and the optimal level of the export tax, etc., export tax does serve as a second-best policy in many cases and has been recommended by many literatures (see analyses below). Historically, the export tax was once adopted by the European countries and has been utilized for various reasons by developing countries in recent decades. Interestingly, little has attributed the export tax to addressing environmental problems which is the case of China. This section first examines the historical use and the rationale of export tax in developed and developing countries. Second, it reviews the incentives of export tax in China which incorporate both conventional uses and the innovative environmental purpose.

2.2.1 Export tax in the pre-World War period

The use of export tax as a component of import/export taxes for trade measures can be dated since the 11th century. However, the most noticeable use of export tax in the pre-World War period is in Europe and particularly in England as a measure of raising revenue, protecting raw materials for domestic industries and eliminating foreign competitions (Goode et al., 1966).

2.2.1.1 Export tax to protect domestic industry:

In England export taxes were applied to raw wool and hides from 1275 to 1660 to promote domestic industry processing (Devarajan et al., 1996). Export taxes served as the most important tool in industrial development during that period since foreign textile producers had to process more expensive raw materials than their English counterparts (Reinert, 2008). Moreover, auxiliary policies were implemented in order to attract foreign investors of wool processing (mainly from Holland and Italy) who could then benefit from the lower price of domestic raw wool in England. Such binding policies ensured the wool-manufacturing capacity growth in England in order to provide sufficient production capacity to process all the wool they produced (Reinert, 2008).

The concept of using export tax policies to ensure low domestic process cost of raw materials and to increase domestic process capacity has also been adopted in the form of a full embargo on raw wool when England was reined by Elizabeth I. However, England was not the first to acquire such an industrial and trade strategy. Similar to Venice and Holland which have used the same methods, England had acquired the same triple rent situation: a strong industrial sector, a raw material monopoly (wool) and overseas trade (Reinert, 2008).

Export taxes were also deployed in this time period in European colonies in Asia and Africa. To some extent, export taxes were designed to raise revenue and to favor the shipment of raw materials to the mother country or other destinations in the empire and the use of national flag vessels (Goode et al., 1966). In the case of the British Empire, export taxes on colonial raw materials were excluded on exports to parts of the British Empire (Viner, 1926).

2.2.1.2 Export tax to eliminate foreign competitions:

The use of export tax on a certain product in a country could also generate a price distortion for foreign competitors which import such product and render domestic industry a comparative advantage over foreign industries which use the same taxed product (James, 1924). For example, the Florentines were not able to compete with their English counterparts because the export duties on English raw wool which ensured a lower access cost to domestic producers in England (Reinert, 2008).

Another example is the earliest British preferential export tax on tin ore from the Federated Malay States. There had been for many years a small export tax, for revenue, on shipments of tin ore, most of which went to British smelters at Singapore (James, 1924). Meanwhile, the United States was planning to develop a smelter industry which is highly reliable on the import of the raw tin from the British Colonies. The larger export tax has then led to a shutdown of all the new smelters in the US since the US smelting industry was not able to compete with English industries. This was further proved by the governor of the Federated Malay States which proclaimed that the export tax had accomplished its intended objective of preventing the transfer of the smelting industry to the United States (James, 1924). Similarly, Britain also used export taxes as a tactic to slow supplies to American soap manufactures and defeat German competition. In 1916, the Britain Parliament enacted a differential export tax on palm kernels from West Africa to prevent German competition and protect oil crushers in Hull, England. Later in the 1920s, the export tax was modified to an export ban which cut off supply to American soap manufacturers (James, 1924).

2.2.2 Nowadays use of export tax in developing countries

Export taxes have been largely eliminated in Europe in recent years despite the fact that they could be adopted when necessary[57]. The US also disapproves the use of

[57] For example, in December 1995, the EU imposed a $35 per ton export tax on wheat (Piermartini, 2004).

export taxes[58] because paragraph 5 of section 9, Article I of the US Constitution forbids export taxes (Gorton, 1924). However, as Piermartini (2004) pointed out, at present time, about one third of the WTO member countries impose export tax and export taxes are mainly used by developing and least-developed countries (LDCs). Of the fifteen LDCs reviewed in the context of the WTO Trade Policy Review Mechanism, ten countries implement export duties, while only three of thirty OECD countries adopt them (Piermartini, 2004).

Piermartini has also explained the incentives of using export tax of which the unique objective is to contribute to ameliorating the economic terms of domestic countries. This is also acknowledged by the EU. “Most countries, to date, have imposed trade restrictions on commodities or other less processed products. This is logical since the measures such as export taxes usually are intended to promote higher value-added activities” (European Commission, 2007). Moreover, “trade restrictions and in particular export duties can sometimes generate an important share of the budget of a country” (European Commission, 2007).

In addition to the economic incentives of enacting an export tax, there are also administrative advantages. According to Devarajan et al. (1996), an export tax is relatively easy to administer and it could potentially raise producing countries’ welfare. Additionally, “as compared with an income or profits tax, the export tax operates more quickly and more directly, although it fails to tap derived gains which may spread through the economy” (Reubens, 1956). And export tax overcomes import tax: “Of course, it is preferable to have lower import taxes and a higher commodity export tax than the opposite because import taxes distort relative prices by taxing all exports as well as non-tradables” (Devarajan et al., 1996). Concretely, the prevailing incentives of using export tax in developing countries can be divided into: (1) government revenue, (2) value added and infant industry, (3) tariff escalation, (4) price stability, (5) terms of trade, (6) currency devaluation and (7) inflation.

2.2.2.1 Government revenue:

Export tax has been used as a financial resource of development particularly in countries producing primary products and/or countries with relatively poor taxation administration (Zee, 2007; Goode et al., 1966; Reubens, 1956). For example, export taxes on rice in Thailand became a major source of government revenue during its industrial development from the 1960s to the 1980s to finance the infrastructure and resources need for industrialization (Warr, 2001). By 1965 rice export taxes alone accounted for one-tenth of total government revenue (Warr, 2001). In turn, with the additional revenue Thailand was able to diversify its economy in agriculture, manufacturing and service industries (Puntasen and Preedasak, 1998).

The use of export tax for revenue reasons is also recommended during commodity

[58] However, the US has implemented preferential export duties on manila hemp from their former colony the Philippines during 1902-1913.

booms. For example, during the Korean War, many countries have established export tax (Goode, Lent and Ojha, 1966; Reubens, 1956). During commodity booms, a very considerable part of the export value tends to disappear in payments for foreign services, overseas remittances of interest, dividends and profits, foreign currencies held abroad, and the flight of "hot money" which can make revenue effects of an export-price boom more uncertain (Reubens, 1956). Export taxes can provide more certainty to governments in this regard by limiting the low of private incomes and enlarging government financial capacities.

However, export tax revenues can be unstable due to fluctuations in the international price of primary commodities and supply fluctuations (Piermartini, 2004). Piermartini (2004) then states that governments can limit the adverse budgetary consequences of a tax system highly dependent on export taxes by establishing a buffer fund, where export tax revenues are deposited when prices are high and from which subsidies to producers are drawn when export prices are low. Nevertheless, the good functioning of the buffer fund depends on the extent of flexibility of political and social institutions.

2.2.2.2 Value-added and infant industries:

Export taxes can be justified on the basis of the infant industry argument (Piermartini, 2004). Countries that specialize in lower value-added sectors (less dynamic manufacturing sectors according to a modern version of the infant industry argument) will be locked into a production structure that entails lower growth rates than those of countries specialized in higher value-added (more dynamic) sectors. Temporary protection or subsidization of a newly established domestic manufacturing industry that is less productive than foreign industries is seen as a way of trying to develop a comparative advantage in that industry (Piermartini, 2004). Export taxes if imposed on primary commodities (especially unprocessed) work as an indirect subsidy to higher value-added manufacturing or processing industries of the domestic country. Export taxes on primary commodities can be used to reduce the domestic price of primary products in order to guarantee supply of intermediate inputs at lower price than world market prices for domestic processing industries. In this way, export taxes provide an incentive for the development of domestic manufacturing or processing industries with higher value-added exports which will benefit from lower domestic prices of inputs and gain competiveness in the international market (Piermartini, 2004; Goode et al., 1966). Some examples of the successful use of export tax to promote domestic processing industries' development can be found on the export tax on timber in Indonesia (Thee, 2009), Russia (Hamilton, 2008; CIBC, 2007) and Canada (BCFED, 2006; Marshall, 2002).

2.2.2.3 Tariff Escalation:

Export taxes can also be implemented as a retaliation policy or strategic response to tariff escalation. Tariff escalation is the practice of charging higher import tariffs on processed goods than on unprocessed ones. Tariff escalation in developed country markets can be detrimental to the development of local high-value processing industries in developing countries (Piermartini, 2004). Many developing countries, for example, Malaysia, Indonesia and the countries of the Africa Group have expressed concern about the adverse effects that tariff escalations have on their economic and social development.[59]

Indeed, the first best policy to combat tariff escalation is for the country imposing them to remove them (Piermartini, 2004). However, this is difficult given that almost all industrial countries practice tariff escalation (Oxfam, 2003). For example, in Canada, the tariff on fully processed foodstuffs is twelve times higher than for products in the first stage (Oxfam, 2003). Japan imposes a zero tariff on raw coffee and cocoa, but this escalates to a 20% and 22% applied tariff respectively for processed coffee and cocoa (Piermartini, 2004). Similarly, USA and EU impose zero tariffs on raw beans of cocoa, but 15% and 20% respectively on paste and chocolate processed from raw cocoa beans. As a result, the development of processing industries of cocoa in developing countries is low: developing countries account for more than 90% of cocoa bean production, less than half of cocoa butter production, and less than 5% of world chocolate production (Oxfam, 2003). Finally, the use of escalated tariffs also dominates on non-food product. For example, the EU imposes a tariff of less than 4% on Indian yarn but 14% tariff on garments processed from yarn. This practice systematically excludes Indian producers from higher growth, higher value-added segments of the market (Oxfam, 2003).

In such regard, an export tax on the unprocessed commodity, by reducing its domestic price, could favor the development of the local processing industry, thus offsetting the distortion effect created by tariff escalation in developed countries (Piermartini, 2004).

2.2.2.4 Price stability:

Commodity price volatility can generate large trade imbalances in a country whose exports depend principally on that commodity (Piermartini, 2004). There exist several first-best solutions in order to lessen the impacts of price fluctuation, for example, to develop more efficient stock markets and financial markets, to introduce a flexible exchange rate regime, to extend the tax base and to improve the tax administration system (Piermartini, 2004). However, such first-best solutions are somehow difficult to be implemented in the short term in developing countries due to institutional constraints. In such regard, export taxes can be used to mitigate commodity price fluctuations on the world market as a second-best policy (Piermartini, 2004). Yet a fixed export tax would not be effective in smoothing the transmission of world price shocks to the domestic economy, governments could impose a high tax rate when world commodity prices increase and reduce or remove the export tax when commodity prices fall. The government could then capture part

[59] For more information visit: http://www.twnside.org.sg/title/tariff-cn.htm and http://www.twnside.org.sg/title2/wto.info/twninfo060710.htm.

of the gains arising from increasing commodity prices and could mitigate the adverse impact of falling prices on producer's incomes.

In fact, many developing countries have used a system of variable export tax rates, imposing high tax rates when export prices are high and vice versa. For example, Papua New Guinea established an export tax/subsidy rate for cocoa, coffee, copra and palm oil equal to one half the difference between the reference price (calculated as the average of the world price in previous 10 years) and the actual price of the year (Piermartini, 2004).

2.2.2.5 Terms of trade:

Export taxes for a long time have been argued as a device to improve a country's terms of trade[60] (Goode et al., 1966; Reubens, 1956). A country with market power can levy an optimal export tax which can target distortion and improve its terms of trade and welfare (Devarajan et al., 1996). In addition, a country with market power will benefit from imposing an export tax, regardless of the behavior of other exporting or importing countries (Piermartini, 2004; Devarajan et al., 1996). In addition, if a big country implements an export tax there will be an improvement of the terms-of-trade for the exporting country, but a worsening of the importing country's terms-of-trade (Piermartini, 2004). The use of export tax or export limitations (quotas) can also be found in various international commodity agreements (ICAs) signed among small export countries in order to increase their terms of trade (Piermartini, 2004; Balassa, 1989; Goode et al., 1966).

2.2.2.6 Currency devaluation:

Export taxes can be used to compensate for a country's currency devaluation (Goode et al., 1966). Export taxes can be levied temporally on exports with low short-run elasticity of supply so the state can attain revenue which would help to control private expenditures and thus support the devaluation (Goode, et al., 1966). For example, in May 1963, Uruguay devalued its peso and increased general export tax rates. As a result, export-tax revenues rose by about 80% between 1962 and 1963. Mexico also raised export tax rates during devaluations of 1938, 1947, and 1954. In 1955, total revenue from export taxes amounted to 15% of export value in Mexico (Goode et al., 1966).

However, the success of using export tax depends on whether a country is "large" and whether it faces a downward sloping demand curve for its exports (Zee, 2007). When a country is a major exporter in a commodity and possesses a degree of market power in the world market then the country's government can impose an export tax when the currency is devalued to derive government revenue. The export tax will allow the government to benefit from the windfall gains received by the exporter due to the devalued currency (Warr, 2001).

[60] "Terms of trade" is the relative prices of a country's exports to imports.

Also, export tax can be used as a substitute of currency appreciation. For example, comparing to currency appreciation, an export tax would render the country's exports more expensive to the rest of the world in apparent similarity to an exchange rate appreciation, but, unlike the latter measure, an export tax would not inflict financial losses on holders of assets denominated in foreign currencies or induce currency speculation (Lau and Stiglitz, 2005).

2.2.2.7 Inflation:

Export taxes have also been identified as a useful tool to combat inflationary pressure. Reuben (1956) explains that "the export tax presents itself as an important and effective device to insulate the domestic economy from some of the inflationary effects of an export boom; and in times of export recession the tax provides something of a cushion against the full impact". Piermartini (2004) explains that firstly, an export tax reduces the domestic price of taxed goods and could offset the inflationary pressures from higher foreign prices. Secondly, an export tax if implemented on primary products helps to reduce the access price of domestic processing industries thus reducing the inflationary pressures by lowering the price of processed products.

2.2.3 Export tax in China

Export tax is used on the products which receive zero export VAT refund rate in China. It has been massively implemented since 2007 (see Table 3). Similar to the use of export VAT refund rebate policies and different to the international experience of export tax, the principal objective of using export tax in China is to curb the export of energy-intensive products and primary resources and products. As table 3 shows, **energy-intensive products together with primary resources account a dominant share among total products submitted to the export tax in China in recent years**. For example, in 2010, 45 iron and steel products (HS-10 digit) receives export taxes rating at 10%, 15%, 20% and 25% and 55 chemical products (HS-10 digit) are imposed similar rates of export tax.

However, **export tax can also be used for other reasons** such as inflation control and to ensure domestic market supply, etc. mentioned above although they can also generate environmental co-benefits. Three examples may worth being highlighted: first, China's policy of using export tax on food export in order to control inflation is one of the successful examples (Lohmar and Gale, 2008). During the 2006-2008 food crisis, more than thirty countries have implemented quantitative export restrictions (FAO, 2008; Karapinar and Haberli, 2010). Food prices in China increased in 2006 and in 2007 the Chinese government decided to prioritize the control of inflationary impact of food prices. In fact, the increasing prices in China were at least partially due to the increasing world commodity prices and also to China's inability to boost domestic production. As a result, China withdrew export VAT refund and introduced temporary export taxes on grain and flour in the light of reducing grain exports and cool domestic grain prices.

Second, China has experienced a domestic coal shortage particularly for electricity generation in 2008 after the outburst of major natural disasters. Facing a rapid increase of domestic coal price, an export tax of 10% has been implemented on the export of coal in August 2008 (Notice of the General Administration of Customs (2008) No.56) in order to ensure the domestic coal supply. Fur the same purpose to lessen domestic thermal power generation, the same notice has also enacted an export tax of 15% on the export of aluminum alloy of which the production is very electricity-intensive.

Finally, the shortage of fertilizers started to dominate in China since 2006. In order to ensure domestic supply capacity of fertilizers, China has implemented a series of policies where two polices are remarkable: first, to impose export taxes (ranging between 20-30% in general for different years and 100% for certain products from April to September 2008) on fertilizers; second, to provide lower electricity and energy prices to fertilizers producers, lower transport costs and charges and to exempt domestic VAT on fertilizers. In this case, the environmental concern of export tax is not pronounced officially despite the fact that there could be environmental benefits that export tax generates.

Table 3. Export tax rates on energy-intensive products and number of total taxed products in China: 2002-2010

Product		2002	2003	2004	2005	2006	2007	2008	2009	2010
Other base metals	Number	1	1	1	1	1	11	15	15	15
(HS81)	Rate (%)	5	5	5	5	5	5,10	5,10,15	5,10,15,20	5,10,15,20
Tin (HS80)	Number							2	2	2
	Rate (%)							10	10	10
Zinc (HS79)	Number						2	3	3	3
	Rate (%)						5	5,10,15	5,10,15	5,10,15
Lead (HS78)	Number							2	2	2
	Rate (%)							10	10	10
Aluminium (HS76)	Number				2	2	2	4	6	6
	Rate (%)				5,10	5,10	15	15	5,15	5,15
Nickel (HS75)	Number				1	2	3	5	5	5
	Rate (%)				2	2	15	5,10,15	5,10,15	5,10,15
Copper (HS74)	Number				3	10	10	13	13	13
	Rate (%)				5,10	5,10	5,10,15	5,10,15	5,10,15	5,10,15
Steel products (HS73)	Number							8		
	Rate (%)							15		
Iron & steel	Number	1		3	3	7	32	113	55	45
(HS72)	Rate (%)	7		5	5	5	10	5,10,15,20,25	5,10,15,20,25	10,15,20,25
Pulp & paper (HS47)	Number							16	16	16
	Rate (%)							10	10	10
Fertilizer (HS31)	Number				1	1	1	3	22	22
	Rate (%)				260yuan/t	*	**	***	75,****	7,30,b
Chemicals (HS28)	Number	1	1	1	1	1	20	47	61	55
	Rate (%)	10	10	10	10	10	5,10	5,10,15,25	5,10, 15,25,a	5,7,10,15,25

Table 3. Export tax rates on energy-intensive products and number of total taxed products in China: 2002-2010 (follows)

Product		2002	2003	2004	2005	2006	2007	2008	2009	2010
Mineral products (HS27)	Number						4	5	12	12
	Rate (%)						5	5,10,15,25	5,10,15,40	5,10,15,40
Mining (HS26)	Number	3	3	1	1	1	36	36	36	36
	Rate (%)	5,10,20	5,10,20	20	20	20	10,20	10,15,20	10,15,20	10,15,20
Total number of EI products		**6**	**5**	**6**	**13**	**25**	**121**	**272**	**248**	**177**
Total number of products taxed at export		**7**	**7**	**7**	**14**	**26**	**137**	**296**	**310**	**265**

Source: Customs House of China and Import Export Tariff of People's Republic of China of related year.

Note: For each sector (HS-2), "Number" indicates the total amount of exported products (HS-8) taxed and "Rate" indicates the export tax rates for related products.

Note: Export tax rates on certain products may vary during a year. The modification is made by the Customs Tariff Commission of the State Council.

Note: * 30% from Jan. 1st to Sep. 30th; 15% from Oct. 1st to Dec. 31st, 2006

** 30% from Jan. 1st to Sep. 30th; 15% from Oct. 1st to Dec. 31st, 2007

*** 30% from Jan. 1st to Mar. 31th; 30% from Apr. 1st to Sep. 30th; 20% from Oct. 1st to Dec. 31st, 2008 for HS31053000 and HS 31054000

30% from Jan. 1st to Mar. 31th; 35% from Apr. 1st to Sep. 30th; 25% from Oct. 1st to Dec. 31st, 2008 for HS31021000

**** 7 products at HS-8 level are given variable export tariff rates

a, special export tax rates 50% on 4 products and 75% on 5 products at HS-8 level.

b, special export tax rates 75% on 8 products at HS-8 level among which 4 products receive differentiated export tax rates by period.

3. Assessment of the climate signal of the current EVRRET policies

The previous part has demonstrated that the incentive(s) of using EVRRET policies in China are rather mixed than simply for environmental protection, despite the fact that the latter constitutes the principal objective of EVRRET and that EVRRET has been announced officially for climate change end. In such regard, this section examines whether such policies could be considered genuine climate policies. It firstly reviews the official proclaims of EVRRET as climate policies and then demonstrates certain drawbacks of EVRRET which hinder to consider them as genuine climate policy.

3.1 Official proclaims and results of interviews

We have seen previously that the export restructure has been defined as one of the governmental work priorities according to different official reports and announcements. More specifically, the use of EVRRET has also been proclaimed as climate policies by major official documents on climate change in China. Firstly, according to China's National Climate Change Programme published in 2007, China engages to "abolish the export tax rebate policy or at least lower the rebate rate for export of steel products". In the official report China's Policies and Actions for Addressing Climate Change published in 2008, it has been clearly stated that "by adjusting tax rebates for exports", "the government is working to restrain the export of high energy-intensive, pollution-intensive and resource-intensive products". Similar political willingness of using the EVRRET policies has been written into the 2009 Progress Report of China's Policies and Actions for Addressing Climate Change, that China has implemented "relevant measures including adjustment of tariffs and tax rebate to curtail the export of the energy-, pollutants emissions-, and resource-intensive products".

Equally, the use of EVRRET policies as an instrument for addressing climate change has been frequently highlighted by senior Chinese officials at different occasions. For example, the vice-Chair of NDRC (minister level) XIE Zhenhua who leads China's climate change actions has pronounced the importance of using EVRRET as taxation policy for addressing climate change in China[61]. China's chief climate change negotiator, Director of Climate Change Department of NDRC has also released words on the necessity of EVRRET as climate policy publicly[62].

In order to provide more evidences on the political willingness of using EVRRET policies for addressing the climate change, we have done several interviews on the opinion of the purpose and incentive(s) of EVRRET with Chinese officials. For the reason of anonymous interviewees, only the institutions are given here. They include: Ministry of Finance, Ministry of Commerce, NDRC, Ministry of Environmental Protection and Counselors Office of the State Council. Two open questions have been

[61] See "XIE Zhenhua: five key achievements of China's actions against climate change", June 26, 2009, http://www.gov.cn/jrzg/2009-06/26/content_1351477.htm (in Chinese).
[62] See "Opportunity of addressing climate change to firms", July 28, 2009, http://www.ccchina.gov.cn/cn/NewsInfo.asp?NewsId=18577 (in Chinese).

selected:

<u>Question A</u>: "What is the principal purpose of using EVRRET policies in China?"

<u>Question B</u>: "Is it necessary to use EVRRET and why?"

Table 4 resumes the results. As seen, energy concerns and the lack of effective domestic environmental and climate prices are the major reason of the use of EVRRET policies in China.

Table 4. Resume of interviews on the use of EVRRET policies with major administrations

Question A: major incentive of EVRRET	Question B: necessity of EVRRET
1. to curb the CO2 emissions as well as other pollutants due to the export of EI products; 2. to reduce energy consumption	It is necessary to use EVRRET as long as the domestic environmental/climate costs are not integrated into the production and the distortive low price of energy exists in China.

Source: Author's interviews.

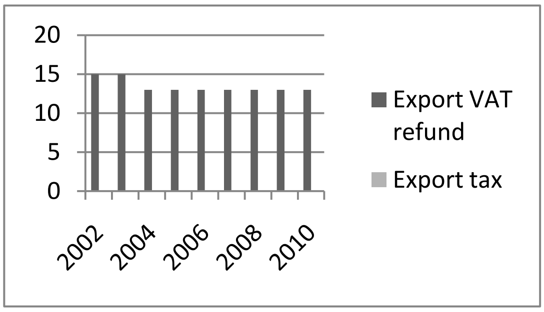
3.2 Lack of comprehensiveness, predictability and stability

As shown above, **the rates of EVRRET vary periodically**. This section provides a precise look on **different examples of the EVRRET rates changes**. EVRRET rates remain stable for certain products while vary (dramatically sometimes) for other products. Plus, EVRRET rates display considerable variations across products and sometimes over time. Generally speaking, a lower rate of VAT refunding (that is higher rate of export VAT non-refunding) has been applied to primary energy-intensive products, when compared to products with relatively higher added value. For example, the export VAT refund rate for aluminum tubes and pipes (HS 76081000) decreased slightly from 15% to 13% in 2004 and has since remained stable at 13% (Figure 1). Similarly, the export VAT refund rate for non-alloy pig iron and cement rate remained stable once it was cut to 0% (Figures 2 and 3). For these products, the cost signal that EVRRET generates is stable in recent year yet not predictable since no official notice ensures the rigidity of the current export VAT refund level.

The export VAT refund rates are sometimes variables and can hardly be considered as genuine environmental policy because of the unstable and unpredictable signal they convey. For example, the export VAT refund rate of certain flat-rolled stainless steel products fell gradually from 15% (in 2002) to 5% (in 2008) before increasing dramatically to 13% in 2009 (Figure 4). This increase was probably intended to enhance export competitiveness of certain energy-intensive products with higher value added in the context of the global economic slump. In this case, export VAT refund policy meets economic objectives rather than environmental ones such as curbing pollution or CO2 emissions.

The evolution of export tax rates when export VAT refund is zero is similar to the case where only export VAT refund rebate applies. For certain products, the level of export tax has remained stable in recent years despite the global economic crisis. For example, the export VAT refund rate of ingots of iron and non-alloy steel (HS72061000) fell to zero in 2005 and 2006 while the export tax implemented as of 2007 remained stable at 25% after 2008, despite the global economic crisis (Figure 5). Similar trends in export tax rates can also be observed for some aluminum products (Figure 6 and 7). Still, the rate of export tax can also vary for some products (Figures 8 and 9) depending on domestic and global market conditions.

Figure 1. Evolution of export VAT refund and export tax rates of aluminum tubes and pipes: 2002-2010. (%)



Note: for all figures, export VAT refund rate is given in positive value and export tax rate is given in negative value.

Figure 2. Evolution of export VAT refund and export tax rates of Non-alloy pig iron containing by weight 0.5% or less of phosphorus: 2002-2010. (%)

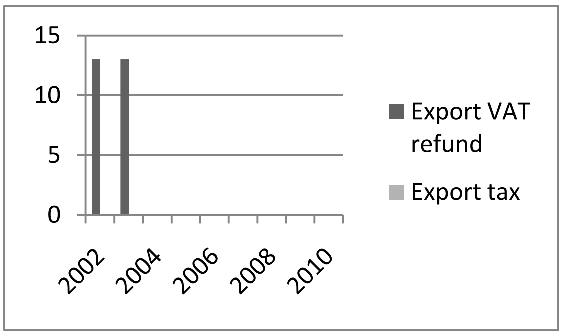
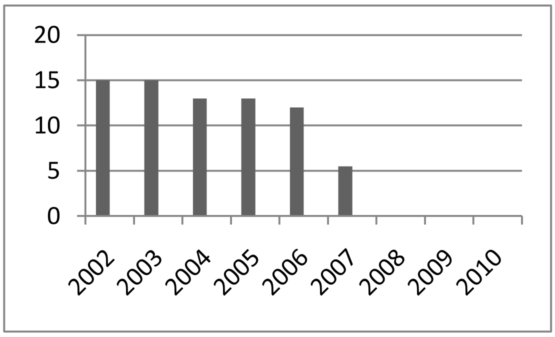
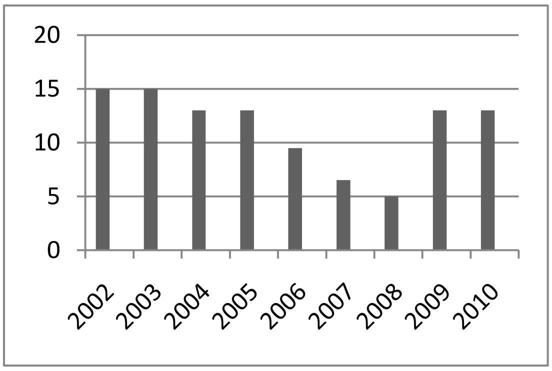


Figure 3. Evolution of export VAT refund and export tax rates of cement: 2002-2010. (%)



Note: 2006 and 2007 export VAT refund rates are average level since export VAT refund rates varied within these years.

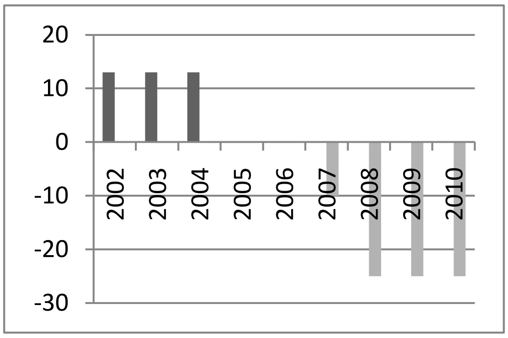
Figure 4. Evolution of export VAT refund and export tax rates of flat-rolled products of stainless steel of a thickness exceeding 10mm: 2002-2010. (%)



Note: 2006 and 2007 export VAT refund rates are average level since export VAT refund rates varied within these years.

Figure 5. Evolution of export VAT refund and export tax rates of ingots of iron and non-alloy steel: 2002-2010 (%)

Figure 6. Evolution of export VAT refund and export tax rates of unwrought aluminum: 2002-2010. (%)



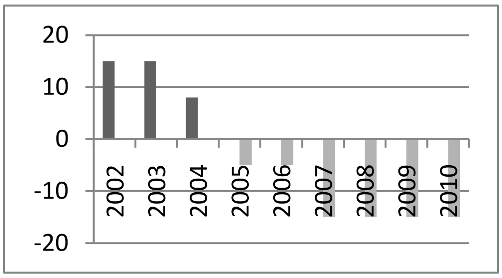
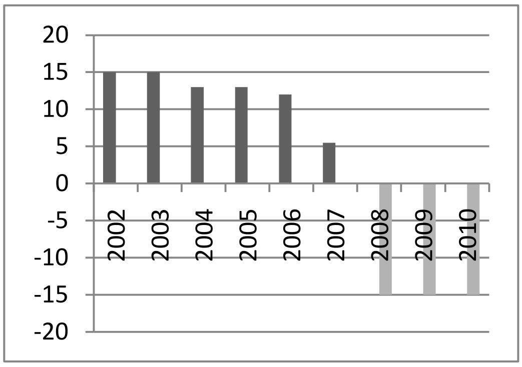
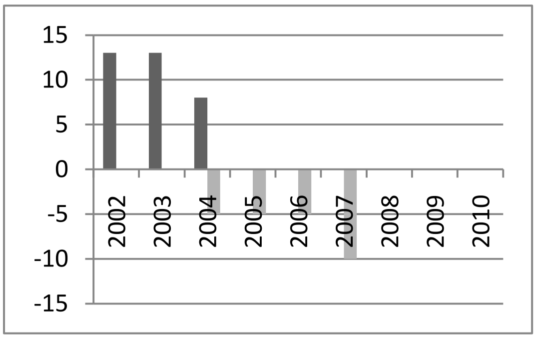


Figure 7. Evolution of export VAT refund and export tax rates of aluminum bars, rods and profiles: 2002-2010. (%)

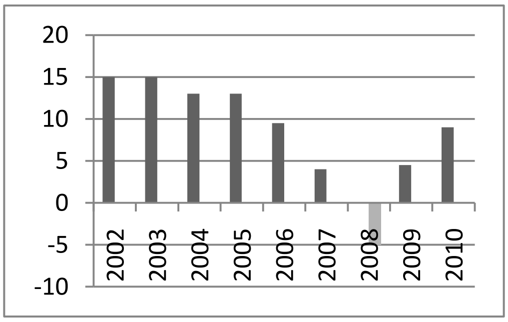
Figure 8. Evolution of export VAT refund and export tax rates of ferro-silico-manganese and ferro-chromium: 2002-2010. (%)





Note: 2006 and 2007 export VAT refund rates are average level since export VAT refund rates varied within these years.

Figure 9. Evolution of export VAT refund and export tax rates of flat-rolled products of steel, electrolytically plated or coated with zinc: 2002-2010. (%)



Note: 2006, 2007 and 2009 export VAT refund rates are average level since export VAT refund rates varied within these years.

4. Assessment of implicit carbon cost and the lack of unique and/or explicit carbon price

In this section, we estimate the **implicit carbon cost** that EVRRET generate on energy-intensive products and sectors in China. We have two objectives by doing so: first, to demonstrate the degree or the extent that EVRRET engenders in terms of carbon price on different products or sectors; second, to demonstrate the lack of unique and explicit carbon price of EVRRET which is another determinant that reduces the genuineness of EVRRET being climate policy.

4.1 Implicit carbon cost that EVRRET generate at product level

As chapter two mentions, the product or sub-sectoral based CO2 emissions and energy consumption (by types) data is not available in China. This has dramatically limited the choice of our calculation of implicit carbon cost that EVRRET generate at product level. However, we can still focus on three representative products, namely crude steel, unwrought aluminum and cement given their relatively higher energy-intensity and sensitivity to carbon leakage and competitiveness problems.

4.1.1 Method

We adopt the following system to estimate the implicit carbon cost. Equation (1) equalizes the "cost" that EVRRET generate to the cost that a carbon price could engender, where for ith product, p_i^{ex} is the export FOB price, VAT_i is the VAT rate, RT_i is the export VAT refund rate, T_i^{ex} is the export tax rate, e_i is the CO2 emission factor per unit of ith product and p_{CO2}^{eq} is the equivalent implicit carbon cost that we calculate, with i = crude steel, unwrought aluminum and cement, respectively. According to the calculation approach defined by the state circular Cai Shui (2004) No.116, the export FOB price (p_i^{ex} here) of a good contains the export VAT refund and/or export tax. The first part on the left side of equation (1) indicates the cost generated by the export VAT refund policy. The second part on the left side of equation (1) indicates the incremental cost that the export tax generates on the ith sector.

$$\frac{p_i^{ex}(VAT_i - RT_i)}{(1+T_i^{ex})(1+VAT_i)} + \frac{p_i^{ex}T_i^{ex}}{(1+T_i^{ex})} = p_{CO2}^{eq}e_i \qquad (1)$$

However, due to data unavailability of unit aluminum CO2 emissions, equation (2) is used to calculate the CO2 emission factor of unwrought aluminum (e_{alum}), where el_{alum} is the electricity consumption of unit aluminum production, E_j is the jth type of fossil fuels that the electricity sector consumed, EC_j is the carbon content of jth energy and TEC is the total electricity generation of the same year. We have therefore assumed 100% combustion rate for all fossil fuels and that the CO2 emissions from sources other than electricity for aluminum production are excluded.

$$e_{alum} = el_{alum}\sum_j E_j EC_j / TEC \qquad (2)$$

4.1.2 Data

2007 data is used in order to prevent any impact of global economic crisis. Table 5 enlists related data of equation (1). The fossil fuel inputs in thermal power generation in China (Energy Statistical Yearbook 2008) and their carbon contents (IPCC, 2006) can be obtained in Chapter Two. In 2007, el_{alum} is 14488kwh/t[63] and TEC is 3281.55 billion kwh. We then obtained e_{alum} at 11.25tCO2/t aluminum.

4.1.3 Results:

With an exchange rate of 1Euro=1.3 US Dollar, the implicit carbon cost that EVRRET generate on crude steel, unwrought aluminum and cement account respectively **43.63 euro/tCO2, 43.06 euro/tCO2 and 5.57 euro/tCO2.** It could be noticed that if process CO2 emissions of aluminum are included, the implicit carbon price would be consequentially lower than 43.06 Euro/tCO2 due to the method setting.

Table 5. Related data of equation 1

	p_i^{ex} (\$/t)[a]	RT_i (%)[b]	T_i^{ex} (%)[c]	VAT_i (%)	e_i (tCO2/t product)
Crude steel (HS7206)	559.61	0	10	17	2.2[d]
Unwrought aluminum (HS76011090)	2452.33	0	15	17	11.25
Cement (HS2523)	34.86	0	0	17	0.7e

Source: a, Custom-Info data base of the General Administration of Customs of China; b, State Taxation Administration of China; c, 2007 Import and Export Tariff of China; d, Hu and Liu (2011); e, Ecofys (2008).

Note: HS7206 includes two products HS72061000 (ingots of crude steel) and HS72069000 (other crude steels) of which the rates of export VAT refund and export tax are identical in 2007.

4.2 Implicit carbon cost that EVRRET generate at sectoral level

In this section we assess the implicit carbon price the EVRRET generate at sectoral level in order to examine the magnitude of EVRRET in terms of carbon price and to demonstrate the extent that EVRRET generate different carbon prices across different sectors.

4.2.1 Method

Still, due to the data constraints, we assume that the technology and energy mix of production for domestic consumption and for export purposes are identical. We use two carbon tax bases here: first, only the direct emissions due to fossil fuel combustion is used according to the definition of environmental taxation which only taxes direct pollution; second, due to the speciality of electricity which could be also considered as an direct “input” for final production, we have also considered the CO2 emissions of electricity consumption as tax base.

[63] Source: the Chinese Central Government website: http://www.gov.cn/banshi/2008-04/07/content_938407.htm (in Chinese)

Therefore, equations 3-4 give respectively the direct CO2 emissions DEi and the sum of the direct and indirect (due to electricity consumption) CO2 emissions DIEi engendered by the export of sector i,

$$\mathrm{DE_i} = \mathrm{S_i}\left(\sum_j \mathrm{E_{ij}} \times \mathrm{C_j} \times \mathrm{rb_j}\right) \quad (3)$$

$$\mathrm{DIE_i} = \mathrm{S_i}\left(\sum_j \mathrm{E_{ij}} \times \mathrm{C_j} \times \mathrm{rb_j} + \mathrm{Ele_i} \times \sum_k \mathrm{El_k} \times \mathrm{EC_k} \times \mathrm{Erb_k}/\mathrm{TEI}\right) \quad (4)$$

where Si denotes the share of the gross value of export for sector i in total sector output. The first part inside the parentheses indicates the direct CO2 emissions of the ith sector, where E_{ij} denotes the consumption of jth type fossil fuel for sector i, C_j denotes the carbon contents of that fossil fuel and rb_j denotes the combustion rate of that fossil fuel. Similarly to 3.1, constrained by the unavailability of data on the exact amounts and specific usages of electricity for any given sector in China, the electricity consumed by each sector is assumed to have the same composition and thus represents an average value. The second part indicates therefore the indirect CO2 emissions caused by the consumption of the electricity of the ith sector ($\mathrm{Ele_i}$), where El_k denotes the electricity generated by the consumption of the kth type of fossil fuel; and EC_k and Erb_k denote respectively the carbon content of the kth fuel and its combustion rate. *TEI* denotes the total electricity (both thermal and non-thermal electricity) generated during a given year.

Recall that the export VAT refund rebate is equivalent to the export tax in that they both add costs to exports and generate revenue for the state. Similar to the approach used in 3.1, this incremental cost is used as an equivalent cost induced by the carbon tax, in order to calculate the implicit carbon tax rates. The implicit export carbon tax for each sector i T^{CO2}_i can be obtained by equation 5-6 using different CO2 emissions bases:

$$\mathrm{P_iQ_iT_i^{Ex}}/\left(1+\mathrm{T_i^{Ex}}\right) + \mathrm{P_iQ_i}\left(\mathrm{VAT_i} - \mathrm{T_i^R}\right)/\left(1+\mathrm{T_i^{Ex}}\right)\left(1+\mathrm{VAT_i}\right) = \mathrm{T_i^{CO\,2}DE_i} \quad (5)$$

$$\mathrm{P_iQ_iT_i^{Ex}}/\left(1+\mathrm{T_i^{Ex}}\right) + \mathrm{P_iQ_i}\left(\mathrm{VAT_i} - \mathrm{T_i^R}\right)/\left(1+\mathrm{T_i^{Ex}}\right)\left(1+\mathrm{VAT_i}\right) = \mathrm{T_i^{CO\,2}DIE_i} \quad (6)$$

where, for a given sector i, P_i and Q_i denote respectively the (average) export (FOB) price and quantity, T_i^{Ex} denotes the average rate of export tax, VAT_i denotes the average VAT rate, and T_i^R denotes the average export VAT refund rate. As mentioned above in 3.1, according to the calculation approach defined by the state circular Cai Shui (2004) No.116, the export FOB price (P_i here) of a good contains the export VAT refund and/or export tax. The first part on the left side of equation 5-6 indicates the incremental cost that the export tax generates on the ith sector. The second part on the left side of equation 5-6 indicates the cost generated by the partial export VAT refund policy.

For a given sector i, the average export tax rate T_i^{Ex} is obtained by

$$T_i^{Ex} = \sum_j T_{ij}^{Ex} P_{ij} Q_{ij} / \sum_j P_{ij} Q_{ij} \quad (7)$$

where j denotes the jth sub-sector classified at HS-4 digit, T_{ij}^{Ex} denotes the average export tax rate of the sub-sector j, and P_{ij} and Q_{ij} denote respectively the export price and quantity of jth product. As exported goods are classified under HS-10 digit, T_{ij}^{Ex} is derived by the following equation (4),

$$T_{ij}^{Ex} = \sum_k T_{ijk}^{Ex} / k \quad (8)$$

where T_{ijk}^{Ex} denotes the export tax rate of kth product at HS-10 for a given jth sub-sector of a given ith sector. This simplified calculation of T_{ij}^{Ex} is motivated by the fact that for the sectors selected, most of the rates of EVRRET of HS-10 products in a given sub-sector (HS-4) are either identical or slightly different. Further, not all data on export volume at HS-10 level are available.

The average export VAT refund rate for a given sector i T_i^R can also be obtained following the same method,

$$T_i^R = \sum_j T_{ij}^R P_{ij} Q_{ij} / \sum_j P_{ij} Q_{ij} \quad (9)$$

where T_{ij}^R denotes the average export VAT refund rate of sub-sector j (HS-4). And based on equation (4), we have

$$T_{ij}^R = \sum_k T_{ijk}^R / k \quad (10)$$

where T_{ijk}^R denotes the export VAT refund rebate of kth product at HS-10 for a given jth sub-sector of a given ith sector.

4.2.2 Data

We use 2007 data, so as to use the most recent and updated energy consumption data, while discarding possible biases induced by the subsequent world economic crisis. The sector (including the electricity sector) final fossil fuel consumption (in physical units), the sector electricity consumption, and total electricity generation (TEI) are available from the China Energy Statistical Yearbook (ESY). The gross value of export and total output of each sector can be obtained from the 2007 input-output (IO) table for the Chinese economy. All data necessary for the calculation is given in Chapter Two.

Table 6 lists the sub-sector components (HS-4) of each selected sector. Sectoral and sub-sectoral annual export volume (P_iQ_i and $P_{ij}Q_{ij}$ in the above equations) is available from Customs-Info database, a database that provides original official Chinese Customs data (see chapter three for detailed instructions). Export tax rates and export VAT refund rebate rates for related products (at HS-10) are obtained from the 2007 *Customs Import and Export Tariff of the People's Republic of China*. Finally, among these energy-intensive sectors, VAT is only below 17% for a few products (for example, gold, condom, etc.). For simplicity of calculation, 17% is adopted as domestic VAT for all selected sectors.

Table 6. Sector division and components

Sector	Components (HS-4)
Iron and steel	HS7201-7229
Basic chemical	HS2801-2853
Petrochemical	HS2701-2716
Non-metallic products	HS2504, 2506-2508, 2520-2525, 6808-6814, 6901-6914, 7001-7020
Non-ferrous metal	HS7106, 7108, 7110, 7401-7415, 7501-7508, 7601-7609, 7801, 7802, 7804, 7806, 7901-7905, 7907, 8001-8003, 8007, 8101-8112
Chemical fibre	HS5401-5408, 5501-5516
Pulp and paper	HS4701-4707, 4801-4823
Rubber	HS4001-4017

4.2.3 Results

Table 7 gives the average sectoral export tax rates and export VAT refund rebate rates (columns 1 and 2) as well as the computed implicit export carbon costs under two different CO2 emission bases. For example, the average export VAT refund rate for the iron and steel sector is 6.89% and this implies that 10.11% is not reimbursed to exporters (as a result of 17% minus 6.89%). Table 7 also shows that the iron and steel, basic chemical and non-metallic products sectors are the major source of export CO2 emissions due to their relatively high export quantities and sectoral energy intensities.

Together with the results shown above of the steel, aluminium and cement products, the result of this section again proves the lack of a unique and explicit carbon price for EVRRET policies in major energy-intensive sectors. According to table 7, the implicit export carbon tax costs that export tax and export VAT refund rebate policies engendered in 2007 diverge substantially among sectors.

Table 7. Implicit sectoral carbon price and other related results

	Sectoral export tax rate (T_i^{Ex}) (%)	**Sectoral export VAT refund (T_i^R) (%)**	**Sectoral direct CO2 emissions from export (DE_i) (Mn t CO2)**	**Implicit sectoral export carbon tax rate (2007 US$/tCO2); tax base DE**	**Sectoral direct and indirect CO2 emissions from export (DIE_i) (Mn t CO2)**	**Implicit sectoral export carbon tax rate (2007 US$/tCO2); tax base DIE**
Iron and steel	1.61	6.89	96.81	41.64	122.96	32.78
Basic chemical	0.44	8.77	39.81	18.38	62.34	11.74
Petrochemical	0.56	1.18	10.01	292.11	11.39	261.37
Non-metallic products	0.012	10.2	20	46.82	29.54	31.69
Non-ferrous metal	1.81	6.92	4.31	494.24	17.90	119.07
Chemical fibre	0	11	0.98	764.59	2.25	332.39
Pulp and paper	0	7.15	2.06	294.09	3.35	181.11
Rubber	0	13	2.26	151.62	8.79	38.99

4.3 Drawbacks of the calculation method

The implicit carbon cost is calculated on the basis of fossil fuel combustion in electricity generation for the aluminium sector. This reduces the unit product CO2 emission level (e_i here) and thus increases the implicit carbon cost that export restrictive policies generate on aluminium. Also, as seen, the lack of data of product carbon intensity has limited the number of products for which the calculation of implicit carbon cost could be made.

5. Conclusion

This chapter reviews the use of export VAT rebate and export tax policies in China. The major findings of this chapter can be grouped as follows:

Incentives of using EVRRET:

The findings in this chapter suggest that **China has not defined any strategies of**

export-led growth on the energy-intensive products. On the contrary, evidence has been repeatedly provided – through official statements – of its willingness to close down energy-inefficient factories, in a context where world import demand has risen faster than domestic capacity changes (China has necessarily acted as a "production capacity reservoir" in the world market to bridge the world supply-demand gap). Certainly, the export taxes might have enabled China to manipulate the terms of trade in order to reap the benefits through export price increases. However, the principal incentive or strategy of using export restrictions on energy-intensive sectors is for energy saving, the modernization of domestic production processes and overall export value gains (and restructuring).

EVRRET as climate commitment:

There are no commitments per se that specifically address climate change – particularly according to EU definitions where emissions reduction targets should be explicit (see the Energy and Climate package) – **that can be formally associated with Chinese EVRRET policies**. In this regard, EVRRET may not be considered a climate policy. However, taxing exports without implementing emission reduction targets can lead to an increase in energy efficiency, and in turn climate change mitigation, even though such an approach does not appear to constitute a formal commitment to cutting GHG emissions. In this regard, EVRRET could be considered as part of a commitment from China towards higher energy efficiency, and in turn, although not explicitly provided with unique and stable carbon price, toward climate change mitigation.

The comparability issue:

This chapter showed that the implicit CO_2 price of China's exports of aluminium and steel could lie in a higher but similar range as the average expected price of the EU-ETS (20-30 €/t CO_2). For these two products, the energy saved in China and the emissions avoided in the EU occur at a comparable value of CO_2 price. At sectoral level, the implicit carbon prices that EVRRET generate for most of the studied sectors are comparable and even superior to EU-ETS carbon price.

This is not true for cement. In this case, the energy saving and carbon intensity objective of China and the emissions reduction targets of the EU cannot be compared, unless export taxes (on a low value product) reach levels of several hundred percent. Setting VAT refund to zero on cement exports might suffice to reach domestic objectives (reducing profit margins, propelling modernisation towards energy efficient plants) but according to the estimates, the negative externality associated with exports is far from the value of the EU CO_2 price equivalent level.

Lack of explicit and stable carbon price:

Finally, both the rates and the taxed products of EVRRET are not stable and predictable. There is neither explicit nor unique carbon price that EVRRET entail.

Such issues render China's export restrictive policy less genuine as climate policy and lead us to the last two chapters which aim to introduce an explicit and comprehensive carbon price into China's export.

References:

Balassa, B., 1989. Tariff Policy and Taxation in Developing Countries, *World Bank Working Paper*, WPS No.281.

British Columbia Federation of Labour (BCFED), 2006. Log Export Crisis in British Columbia: A Time to Act, *BCFED Report*.

Canadian Imperial Bank of Commerce (CIBC) World Markets, 2007. Russian Log Export Tax, *Equity Research Industry Update*, March 13, 2007.

Choeun, H., Yoshihisa G., Yujiro, H., 2006. The economics and politics of rice export taxation in Thailand: A historical simulation analysis, 1950-1985, *Journal of Asian Economics*, 17, pp.103-125.

Devarajan, S., Delfin, G., Maurice, S., Suthiwart-Narueput, S., 1996. The Whys and Why Nots of Export Taxes, *Policy Research Working Paper* 1684, World Bank.

Ecofys, 2008. Factors underpinning future action – country fact sheets 2008 update.

Edminster, L.R., 1930. Control of Exports of Raw Materials: An International Problem, *Sage Publications, Inc.* no. 150.

European Union Commission, 2007. State of play of work on trade restrictions affecting access to raw materials, Available from http://trade.ec.europa.eu/doclib/docs/2008/february/tradoc_137761.pdf

European Union Commission, 2008. The raw materials initiative – meeting a critical needs for growth and jobs in Europe, Communication from the Commission to the European Parliament and the Council (2008), http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=894&userservice_id=1&request.id=0.

Food and Agriculture Organisation of the United Nations (FAO), 2008. Policy measures taken by governments to reduce the impact of soaring prices, *Crop prospects and food situation*, FAO: Rome, pp.13-17.

Goode, R., George E.L., Ojha, P.D., 1966. Role of Export Taxes in Developing Countries, *Staff Papers-International Monetary Fund* 3, No. 13.

Hamilton, G., 2008. Russian export tax opens log markets for local, *Vancouver Sun*. Friday, May 02, 2008.

He, D., Zhang, W., 2010. How dependant is the Chinese economy on exports and in what sense has its growth been export-led?, *Journal of Asian Economics*, 21, pp.87-104.

Hu, X., Liu, Q., 2011. Potential role of sectoral approach for carbon emission reduction in international climate mechanism, case study on the iron and steel sector in China, Draft, *Climate Strategies Working Paper* 10 January 2011. http://www.climatestrategies.org/component/reports/category/54/311.html

James, G., 1924, British Preferential Export Taxes, *American Economic Association* 1, no. 14.

Karapinar, B., 2010. Export restrictions on natural resources: policy options and opportunities for Africa, World Trade Institute Paper. http://www.wti.org/fileadmin/user_upload/nccr-trade.ch/news/TRAPCA%20Paper%20(Submitted1711)_BK.pdf

Karapinar, B., Haberli, C., Eds, 2010. *Food crisis and the WTO*, Cambridge University Press, Cambridge.

Kahrl, F., Roland-Holst, D., 2007. Energy and exports in China, *China Economic Review*, 19(4), pp.649-658.

Lau, L., Stiglitz, J., 2005. China's alternative to revaluation, Financial Time, 25/04/2005, available at http://www.ft.com/cms/s/0/cb1955ca-b533-11d9-8df4-00000e2511c8.html#axzz1KcGutAJf

Lohmar, B., Fred, G. 2008. Who Will China Feed?, *Economic Research Service/USDA*, Vol. 6, no. 3, pp.10-15.

Marshall, D., 2002. Down the Value Chain: The Politics and Economics of Raw Log Exports, *Canadian Centre for Policy Alternatives*, (November 20, 2002): 1-6.

McMillan, M., Horn, K., Rodrik, D., 2003. When Economic Reform Goes Wrong: Cashews in Mozambique, available at http://www.hks.harvard.edu/fs/drodrik/Research%20papers/nuts.pdf

Oxfam, 2003. Running into the Sand, *Oxfam Briefing Paper 53*, http://www.oxfam.org.uk/resources/policy/trade/downloads/bp53_cancun.pdf.

Parker, E., Thornton, J., 2007. Fiscal Centralisation and Decentralisation in Russia and China, *Comparative Economic Studies*, 49, pp.514-542.

Piermartini, R., 2004. The Role of Export Taxes in the Field of Primary Commodities, *World Trade Organization*, available at, http://www.wto.org/english/res_e/booksp_e/discussion_papers4_e.pdf.

Puntasen, A., Preedasak, P., 1998. Agriculture in Thailand at the Cross-Road. *ASEAN Economic Bulletin*, Vol. 15, no. 1, pp.90-107.

Reinert, E.S., 2008. *How Rich Countries Got Rich…and Why Poor Countries Stay Poor*. Wimbledon Publishing Company and Anthem Press, India.

Reubens, E., 1956. Commodity Trade, Export Taxes and Economic Development, *The Academy of Political Science* 1, no. 71, pp.42-70.

Thee, K.W., 2009. The Indonesian wood products industry, *Journal of the Asia Pacific Economy*, 14(2), pp.138-149.

Viner, J., 1926. National Monopolies of Raw Materials, *Council on Foreign Affairs* 4, no. 4, pp.585-600.

Warr, P., 2001. Welfare Effects of an Export Tax: Thailand's Rice Premium, *American Journal of Agricultural Economics*, 83(4), pp.902-920.

Zee, H.H., 2007. Export Taxes in Times of Trade Surpluses. *Journal of International Trade & Economic Development*, 16(2), pp.137-157.

Zheng, Y., Qi, J., Chen, X., 2011. The effect of increasing exports on industrial energy intensity in China, *Energy Policy*, 39, pp. 2688-2698.

Chapter Six. Using partial non-refundable export VAT as an explicit and predictable climate policy

1. Introduction

We have demonstrated in Chapter Five that export VAT refund rebate and export tax (EVRRET) policies have been used in China principally on energy-intensive sectors for energy and climate concerns. There exists some quantitative literature on the effectiveness of China's export VAT rebate policy (for example, Chen et al., 2006) However, little has discussed the climate pertinence of such policies. EVRRET lacks in explicit, stable and predictable carbon price and therefore fall short on genuine climate policy. In order to improve the comprehensiveness and transparency of the climate policy in China both for domestic low carbon economy (LCE) development and effectively curbing the carbon leakage thus consolidating international efforts of addressing climate change, this chapter provides a method that explicitly defines a unique carbon price for exports from major energy-intensive sectors and assures easy short-term implementation, compatible with the original nature and efficiency of EVRRET policies.

We focus on eight energy-intensive sectors, since they are mentioned in official plans and have the highest energy intensity according to analysis of Chapter Four. The rationale of taxing only the export of energy-intensive products for energy-saving and climate change purposes instead of taxing all exports is at least threefold. First, EVRRET policies, if accounted on the direct CO2 emissions of a product, could engender a significant increase in ad valorem export tax rates for such sectors and therefore generate visible climate effects. For other non energy-intensive sectors, however, the export tax would only create a negligible marginal effect, as the share of carbon cost in total value added is low[64]. Second, the export of certain final products with higher value-added and technology contents are promoted despite the negative climate external cost they generate. Third, as mentioned above and as will be shown below, export tax and VAT refund rebate policies have already been massively implemented in energy-intensive sectors relative to other sectors in recent years. The introduction of clear carbon pricing on such sectors requires no further tax creation, but only varies the tax rates or tax structure, which could dramatically facilitate the administrative process of introducing a carbon price.

This chapter is organised as follows: Part two demonstrates method of introducing explicit and unique carbon cost into EVRRET policy and shows how such carbon price could be modified and converted into product export VAT refund (or non-refund) rates. Part three provides an alternative method of introducing a predictable but not unique carbon cost into the EVRRET as a second-best solution for the previous

[64] This will be proved by the quantitative assessment of the following chapter.

proposal. Part four recommends the implementation timeline of such policy before concluding.

2. Introducing predictable and explicit carbon cost into non-refundable export VAT
We now consider that a unique carbon price is allocated to the export of major energy-intensive products that already receive export tax and/or export VAT refund rebate. Therefore, this explicit carbon policy can be implemented either by export tax or by export VAT refund by defining a unique and stable carbon cost based on direct emissions of export goods. This section examines whether an explicit and stable carbon price can be introduced into current EVRRET policies without generating additional competitiveness problems on China's export.

2.1 Mehtod
2.1.1 Introducing explicit carbon cost into non-refundable export VAT
Under the assumption that the export taxes are kept at their actual level, the equivalent rate of export VAT refund (alternatively named "equivalent rate of export VAT non refunding" which is the difference between 17% as domestic VAT and the equivalent rate of export VAT refund) to a given carbon price is determined by equalizing the cost engendered by CO2 emissions for the export product of a sector and the cost that the export VAT refund rebate engenders. For a sector i, it can be given by equations 1-2 which take different account of only direct emissions and both direct and indirect emissions (similar definition to the previous chapter):

$$P_i Q_i \left(VAT_i - T_i^{R,Op}\right) / \left(1 + T_i^{Ex}\right)\left(1 + VAT_i\right) = T_i^{Op,CO2} DIE_i \qquad (1)$$

$$P_i Q_i \left(VAT_i - T_i^{R,Op}\right) / \left(1 + T_i^{Ex}\right)\left(1 + VAT_i\right) = T_i^{Op,CO2} DE_i \qquad (2)$$

where $T_i^{R,Op}$ denotes the explicit export VAT refund rate for climate change purposes that we calculate, and $T_i^{Op,CO2}$ denotes the given carbon tax rate with other symbols having the same definition to the previous chapter.

2.1.2 Introducing explicit carbon cost into export tax
Under the assumption that the current export VAT refund rates are kept at their actual level, we can also obtain the explicit export tax rate for climate change purposes by equalizing the CO2 emissions cost and the cost generated by export tax for a given sector. For a certain sector i, it can by written by equations 3-4:

$$P_i Q_i T_i^{Ex,Op} / \left(1 + T_i^{Ex}\right) = T_i^{Op,CO2} DIE_i \qquad (3)$$

$$P_i Q_i T_i^{Ex,Op} / (1 + T_i^{Ex}) = T_i^{Op,CO2} DE_i \qquad (4)$$

where $T_i^{Ex,Op}$ denotes the explicit export carbon tax rate corresponding to the given (unique) carbon tax rate with other symbols having the same definition to the previous chapter.

2.2 Data

Table one gives the sub-sector components (HS-4) of each selected sector. Sectoral and sub-sectoral annual export volume (P_iQ_i and $P_{ij}Q_{ij}$ in the above equations) is available from Customs-Info, a database that provides original official Chinese Customs data (See Chapter Two for details). Export tax rates and export VAT refund rebate rates for related products (at HS-10) are obtained from the 2007 *Customs Import and Export Tariff of the People's Republic of China*. Finally, among these energy-intensive sectors, VAT is only below 17% for a few products. For simplicity of calculation, 17% is adopted as domestic VAT for all selected sectors. The sources and values of other data are given in chapter two.

Table 1. Sector division and components

Sector	Components (HS-4)
Iron and steel	HS7201-7229
Basic chemical	HS2801-2853
Petrochemical	HS2701-2716
Non-metallic products	HS2504, 2506-2508, 2520-2525, 6808-6814, 6901-6914, 7001-7020
Non-ferrous metal	HS7106, 7108, 7110, 7401-7415, 7501-7508, 7601-7609, 7801, 7802, 7804, 7806, 7901-7905, 7907, 8001-8003, 8007, 8101-8112
Chemical fibre	HS5401-5408, 5501-5516
Pulp and paper	HS4701-4707, 4801-4823
Rubber	HS4001-4017

2.3 Results

Table two and three list the sectoral ad valorem rates for export tax and export VAT refund under explicit carbon pricing on exports by using different sectoral CO2 emission bases. Two options are therefore available: first, an export VAT refund rate (equivalent to export VAT non refund rate) corresponding to a unique carbon cost may be used as the maximum refund rate (or minimum non-refund rate) for each sector. The export VAT refund rate could be reduced based on this maximum level for other domestic or export policy needs. Export tax, in this case, could still be implemented and adjusted periodically for non-climate ends. Second, export tax rates corresponding to a given unique carbon cost could be fixed as a minimum export carbon tax level. Export VAT refund rebate and export tax (in case of zero export VAT refund rate) could be adjusted for non-climate purposes.

Comparing table seven of the previous chapter and table two of this chapter, **the introduction of an explicit carbon cost into the export tax would be more difficult** in terms of additional export costs that such an introduction of carbon price could entail. First, such measure requires a general increase in export tax rates. This risks causing domestic resistance due to concerns regarding competitiveness. Second, given that many products are not currently taxed yet on their export, this could increase the administrative charge of managing the export tax for new products. Finally, as will be shown by the following chapter, the use of export tax risks generating WTO disputes.

Nevertheless, **the introduction of explicit carbon price into export VAT refund** (or export VAT non refund) **as climate taxation seems highly feasible**. At sectoral level, the introduction of 20\$/tCO2 which only accounts direct sectoral CO2 emissions is the most feasible option. It will only require a further reduction in the current export VAT refund rate (alternatively speaking, an increase of the export VAT non-refunding rate) in chemical sectors, whereas a reduction in current export VAT refund would not be required for other sectors. This measure merely aims to set a clear division on the actual export VAT refund rate which is already lower than the equivalent export VAT refund rate that the explicit carbon cost generates. This process would be similar to the Swedish experience of implementing a domestic carbon tax, which was introduced by splitting the existing energy tax into half energy tax and half carbon tax without adjusting the final tax burden.

We can illustrate this process by using iron&steel sector as an example. As seen, the 2007 level of export VAT refund rate for the iron and steel sector is 6.89% (table seven of Chapter Six) which can be alternatively accounted at 10.11% as export VAT non-refunding rate given the domestic VAT at 17%. According to table three, the equivalent sectoral export VAT refund rate that the explicit carbon cost (20\$/t CO2) generates is 9.68% if only sectoral direct CO2 emissions are taken into account. Similarly, this leads to an export VAT non-refunding rate of 7.32%. The introduction of an explicit and stable carbon cost (20\$/tCO2) will not require an increase on the current export VAT non-refunding rate, thus will not generate extra competitiveness burdens on iron&steel sector. 7.32% must be announced as fixed export VAT non-refunding rate for climate change reason. The advantage of this approach is that it does not prohibit increasing and varying further export VAT non-refunding rate beyond the fixed level of 7.32%. In this example of iron&steel sector, the 2.79% (the difference between 10.11% and 7.32%) of export VAT non-refunding could be defined as an objective to curb domestic pollution that the production of iron and steel engendered and could be modified in the future for other uses and incentives than climate change.

Table 2. Ad valorem rates of export tax or export VAT refund rebate under explicit export carbon taxation policy (%) (taxe base is direct+indirect CO2 emissions)

	20$/t CO2			30$/t CO2		
	Export tax ($T_i^{Ex,Op}$)	Export VAT refund ($T_i^{R,Op}$)	Equivalent export VAT non-refund rate	Export tax ($T_i^{Ex,Op}$)	Export VAT refund ($T_i^{R,Op}$)	Equivalent export VAT non-refund rate
Iron and steel	7.20	9.68	7.32	10.80	6.02	10.98
Basic chemical	14.84	2.10	14.90	22.26	-5.36	22.36
Petrochemical	1.25	15.74	1.26	1.88	15.11	1.89
Non-metallic products	4.30	12.70	4.30	6.45	10.55	6.45
Non-ferrous metal	2.01	14.95	2.05	3.02	13.93	3.07
Chemical fibre	0.36	16.64	0.36	0.54	16.46	0.54
Pulp and paper	1.09	15.91	1.09	1.63	15.37	1.63
Rubber	2.05	14.95	2.05	3.08	13.92	3.08

Table 3. Ad valorem rates of export tax or export VAT refund rebate under explicit export carbon taxation policy (%) (tax base is direct CO2 emissions)

	20$/t CO2			30$/t CO2		
	Export tax ($T_i^{Ex,Op}$)	Export VAT refund ($T_i^{R,Op}$)	Equivalent export VAT non-refund rate	Export tax ($T_i^{Ex,Op}$)	Export VAT refund ($T_i^{R,Op}$)	Equivalent export VAT non-refund rate
Iron and steel	5.67	11.24	5.76	8.5	8.36	8.64
Basic chemical	9.48	7.48	9.52	14.21	2.72	14.28
Petrochemical	1.12	15.87	1.13	1.68	15.31	1.69
Non-metallic products	2.91	14.09	2.91	4.37	12.63	4.37
Non-ferrous metal	0.48	16.51	0.49	0.73	16.26	0.74
Chemical fibre	0.16	16.84	0.16	0.24	16.76	0.24
Pulp and paper	0.67	16.33	0.67	1	16	1
Rubber	0.53	16.47	0.53	0.79	16.21	0.79

2.4 Setting ad valorem equivalent export non-refunding rates for products

We have seen that the introduction of an explicit carbon cost into the export VAT non-refunding policy could be highly feasible at sectoral level. However, export VAT refund policy is based on product in practice. In this section, we examine whether the above mentioned proposal is feasible at product-based level. In theory, three options are available for setting equivalent export VAT non refunding rates at product-level (HS-10) based on results obtained at sectoral level.

First, and the most ideal way, the equivalent export VAT non-refunding rates for exported products may be obtained based on the CO2 emissions of each product. This requires a complex accounting system that is unavailable in the short term. However, an emission accounting mechanism at the sub-sectoral level (HS-4) may be technically feasible in the following way: extending the ongoing capacity building process for GHG emissions from fossil fuel inventories in order to obtain related energy consumption and/or CO2 emissions information at the sub-sectoral level, or using estimation measures that enable to approach real emissions.

Second, the equivalent export VAT non-refunding rates can be obtained using weighting measures based on current export tax and VAT refund rebate rates. Several choices are available for the weighting units, for example the share of the export (in volume or in physical quantity) of a product in the total export of the sector, or the share of the rate of the export tax or export VAT refund of a product in the sum of the export tax rates or VAT refund rebate rates of a sector, etc. However, such method allocates product equivalent export VAT non-refunding rates which have no link to their CO2 emissions.

Finally, an identical rate can be applied to all products for a given sector. This would be unwise for those sectors where specific CO2 emissions are very heterogeneous, for example the non-metallic product sector (which includes cement and clinker). For this situation, equivalent export non-refundable VAT rate could be calculated at product or sub-sectoral level where data is available. For example, the equivalent export non-refundable VAT rates of cement and aluminium could be obtained at product level which will differ from the rates obtained at sectoral level (cement for non-metallic products and aluminium for non-ferrous metal products). However, given the actual lack of data for most of the sub-sectors and products, this method of introducing a unique export non-refundable VAT rate at sectoral level could be applied given its simplicity and could still be highly relevant for sectors where the CO2 emissions differ relatively slightly among products, for example, the iron&steel sector.

We examine now whether a carbon price can be introduced into the latest 2011 export VAT refund rates. As demonstrated in the previous chapter, the export VAT refund rates could vary across years. For chemical fibre sector, the export VAT refund rate of all 660 chemical fibre products (HS-10) was 11% (equivalent to 6% of export VAT non-refunding rate) in 2007 yet this rate has been increased to 16% (equivalent to only 1% of export VAT non-refunding rate) in 2011 probably due to the economic crisis. However, such increase of export VAT refund rates does not really dismiss the willingness of curbing the export of EI products and rather, the fibre chemical sector is more or less an exception. As shown by table four, most of the products (and particularly most of the primary products) of other EI sectors other than chemical fibre sector still receive zero or low export VAT refund rates (equivalent to high export VAT non-refunding rates).

Table 4. Export VAT non refunding rate of eight major EI sectors at HS-10 in 2011

	Number of products at HS-10								
Export VAT non refund rate	**Iron&steel**	**Basic chemical**	**Petrochemical**	**Non-metallic products**	**Non-ferrous metal**	**Chemical fibre**	**Pulp&paper**	**Rubber**	**Total**
17%	128	355	75	66	216	0	115	23	**978**
12%	6	4	0	50	11	0	3	21	**95**
8%	29	4	0	16	11	0	0	98	**158**
4%	55	5	1	67	51	0	33	7	**219**
2%	0	0	0	0	6	0	0	0	**6**
1%	0	0	0	0	0	660	0	0	**660**
0%	0	1	0	0	1	0	0	0	**2**

Source: Author's rearrangement based on data from State Administration of Taxation website.

We provide thereafter a sector-by-sector analysis of the feasibility of introducing explicit and stable carbon price into the export VAT non-refund policy. In order to prevent repeating, in the following parts until the end of the section 2.4, "product(s)" is measured by HS-10 and "sector" is classified under HS-4 digit level.

Iron and Steel:

In 2011, most of the iron and steel products receive zero export VAT refund rates. Figure one shows the magnitude of products number with different export non-refundable VAT rates and compares them with different level of equivalent export non-refundable VAT rates that different explicit carbon prices with different emission bases generate. As seen, the introduction of 20$/tCO2 with both tax base of only direct CO2 emissions and direct + indirect CO2 emissions would only require an increase of export non-refundable VAT rates of 1.76% and 3.32%, respectively for 55 steel products (HS-10). Further, the introduction of an explicit carbon price of 30$/tCO2 would require increasing the export non-refundable VAT rates of an additional number of 29 steel products. For both cases of explicit carbon prices, such products usually have longer process chains and higher value-added and the introduction of an explicit carbon price would generate further competitiveness problems on the export of such products.

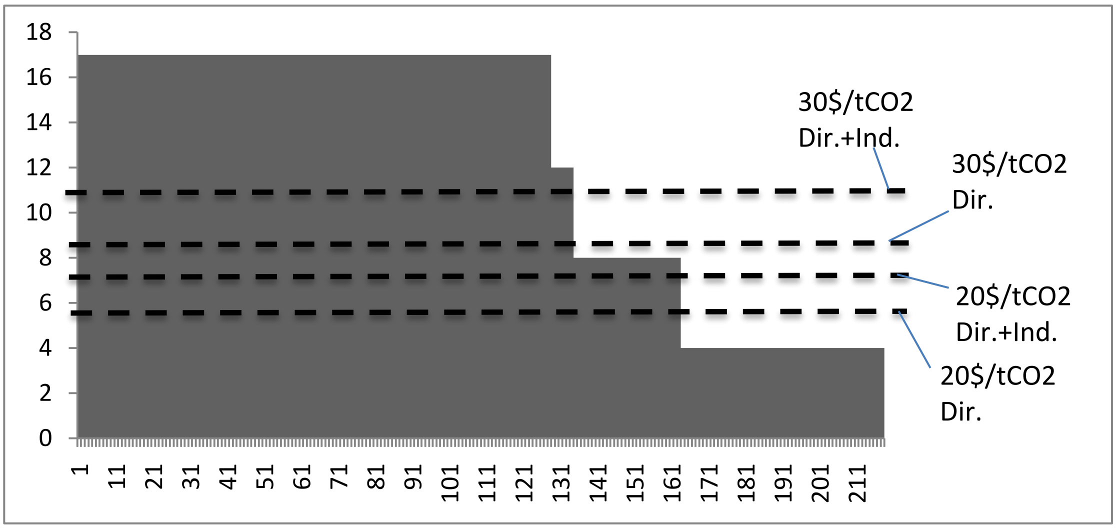
However, on the other side, the introduction of an explicit carbon price would not generate competitiveness problems for 128 and six products receiving respectively 17% and 12% export non-refundable VAT rates for both cases of explicit carbon prices.

Two solutions are feasible for having a unique and explicit carbon price at iron and steel sector. First, to reduce the explicit carbon price to a degree which generates an equivalent export non-refundable VAT rates lower than 4%. Therefore, the introduction of the carbon price would not generate any additional cost on the export of the whole sector. However, this would also lead to a general export explicit carbon price decrease thus lowering the climate policy stringency. Second, if the explicit carbon price (for example 20$/tCO2) is maintained, the policy maker would increase the export non-refundable VAT rates for these steel products with an anticipation that these steel products would encounter potential short-term competitiveness impacts.

If the second option could be achieved and if 20$/tCO2 with only direct emissions as tax base is selected as explicit carbon price, this would require a fixation of minimal export non-refundable VAT rate of 5.76% and could be considered very feasible in terms that such introduction would not generate significant short-term competitiveness impacts on the whole iron&steel sector. Still, as mentioned above, the advantage of such explicit carbon price introduction is that it does not hinder any further variation of total export non-refundable VAT rates for each product as long as the minimal equivalent rates for climate change ends is respected. Therefore, it leaves sufficient policy spaces (flexibility) for export VAT refund policy to be adopted for other non-climate change ends[65].

[65] For the analysis of other sectors below, the policy flexibility is omitted in order to avoid repeating.

Figure 1. Export non-refundable VAT rates by product of iron&steel sector: 2011



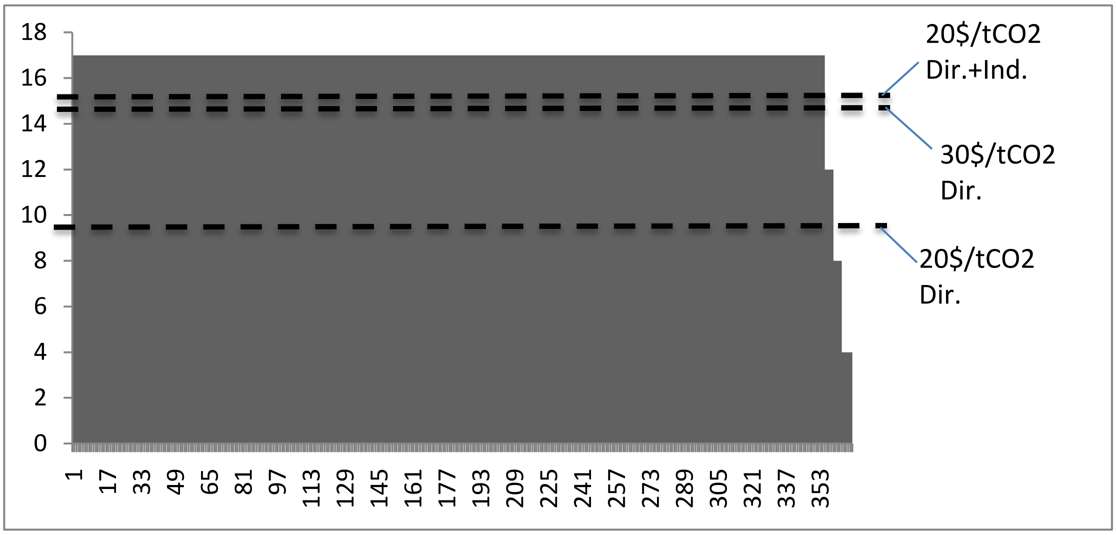
Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.
Source: Author.

Basic Chemical:

The basic chemical sector has seen a general reduction of export VAT refund (equivalent to an increase of export VAT non-refund) in 2011 comparing to 2007 level. This has dramatically facilitated the introduction of explicit and stable carbon price into this sector given that almost all the products receive in 2011 zero export VAT refund rebate. As Figure two shows, the introduction of 20$/tCO2 both with direct and direct+indirect CO2 emissions as tax bases would not generate further competitiveness problems given that the equivalent export non-refundable VAT rate is lower than the current export non-refundable VAT rate that almost all products receive in 2011. Notably, the introduction of 30$/tCO2 taking both direct and indirect CO2 emissions as tax basis will require zero export VAT refunding plus an export tax of 5.36%. The introduction of the carbon price under such a case would be more difficult given the additional export cost it entails.

In terms of policy space, the introduction of 20$t/CO2 with direct CO2 emissions as tax base would leave larger policy flexibility for non-climate change objectives of export VAT refund policy. This might be judged an additional advantage of introducing this carbon price.

Figure 2. Export non-refundable VAT rates by product of basic chemical sector: 2011

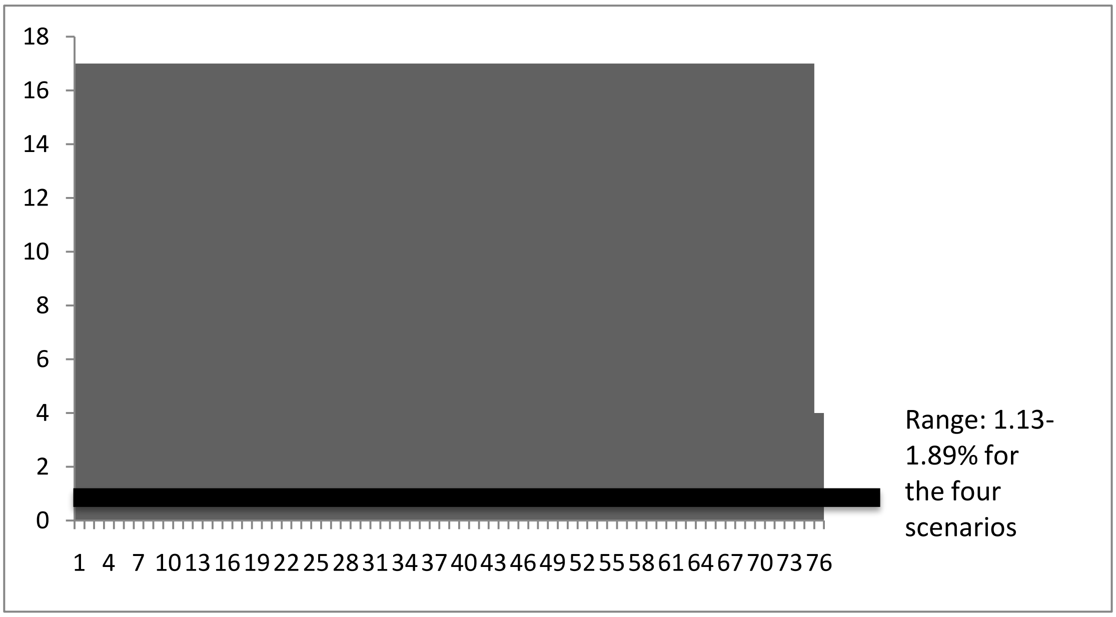


Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.

Petrochemical sector:

Almost all of the petrochemical products receive zero export VAT refund in 2011 and this allows easily the introduction of an explicit and stable carbon price. As shown by figure 3, the introduction of both 20 and 30$/tCO2 with both tax bases would only generate a small range of differences: their equivalent export non-refundable VAT rates vary between 1.13% to 1.89% which are much lower than the current rates that petrochemical products receive.

Figure 3. Export non-refundable VAT rates by product of petrochemical sector: 2011

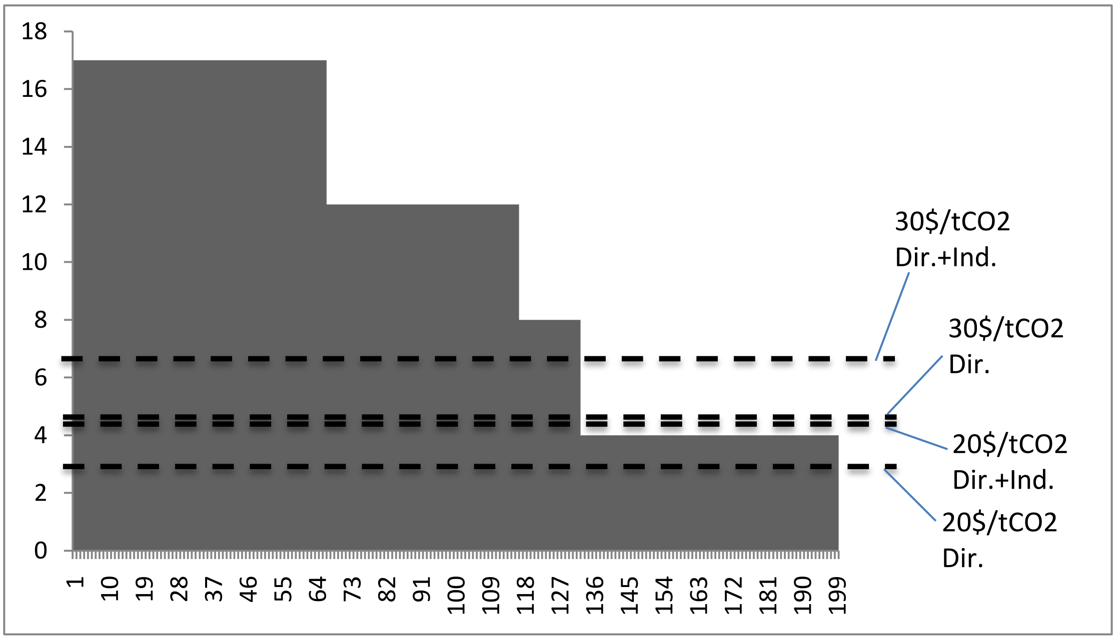


Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.

Non-metallic product sector:

About two third of non-metallic products receive low export VAT refund rates and one third receives medium rates in 2011. However, the relatively lower equivalent export VAT non refund rates have ensured the introduction of explicit carbon price. As figure 4 shows, the introduction of 20$/tCO2 with direct CO2 emission as tax base would not generate any competitiveness problems given that the current export VAT non-refundable rates are higher than the equivalent rate that 20$/tCO2 generates. Also, the introduction of 20$/tCO2 with direct+indirect CO2 emissions tax base and the introduction of 30$/tCO2 with direct CO2 emissions tax base would require a very slight increase of the export non-refundable VAT rate for 67 products which could be considered feasible. Finally, an introduction of 30$/tCO2 with direct+indirect CO2 emissions tax base would require an increase of more than 2% of the export non-refundable VAT rate of the same 67 products while would not generate additive competitiveness problems for the rest of the products of the sector.

Figure 4. Export non-refundable VAT rates by product of non-metallic product sector: 2011



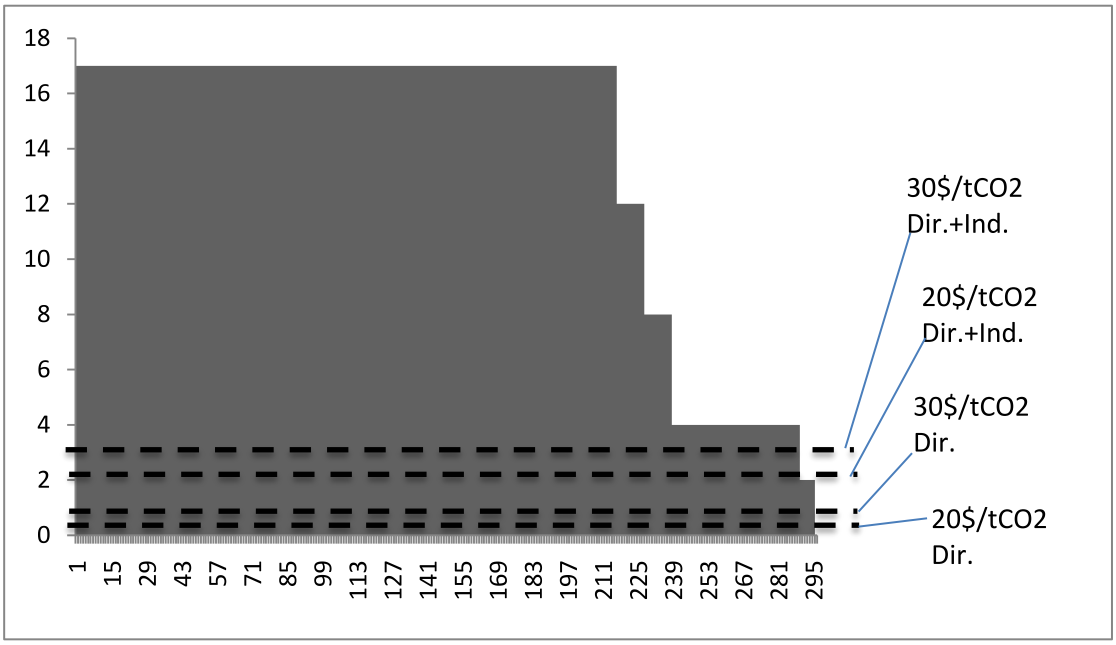
Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.

Non-ferrous metal sector:

Most of the non-ferrous metal products are imposed zero export VAT refund despite the fact that around one fifth of the products is imposed higher export VAT refund rates in 2011. As shown by figure five, the introduction of both 20 and 30$/tCO2 with direct CO2 emissions tax base would not generate competitiveness problems given that the equivalent export non-refundable VAT rate is lower than the current export non-refundable VAT rates of products of the sector. If the tax base is direct+indirect

CO_2 emissions, the introduction of 20 or 30\$/tCO_2 would only require an increase of export non-refundable VAT rates for 7 products. Therefore, all four scenarios of the introduction of an explicit carbon price could be considered feasible for non-ferrous metal sector.

Figure 5. Export non-refundable VAT rates by product of non-ferrous metal sector: 2011



Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.

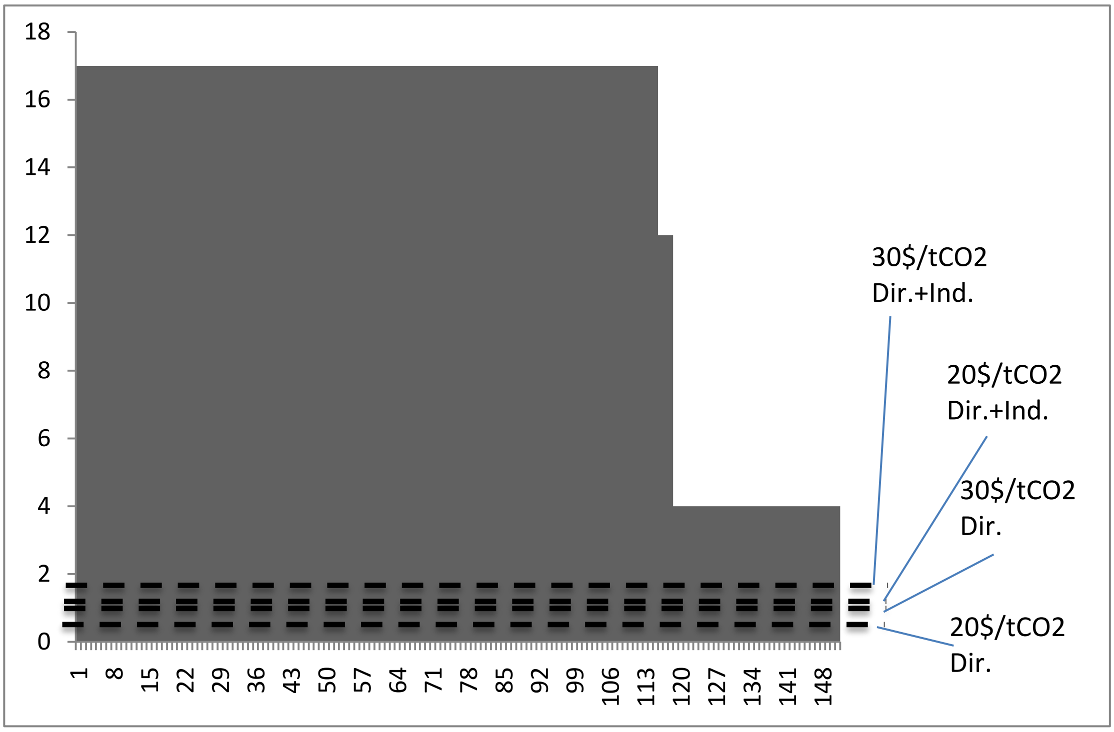
Chemical fibre:

As mentioned above, the export VAT refund rate of chemical fibre products (HS-10) of chemical fibre sector have been increased to 16% in 2011. This is equivalent to a very low rate of export non-refundable VAT (only 1% for all products in the sector). However, given that the equivalent export VAT non-refund rates that all four scenarios generate are also low and inferior to 1%, the introduction of an explicit carbon price would generate no competitiveness problems.

Pulp and paper:

The export VAT refund rates are low for most pulp and paper products in 2011, thus giving the high export non-refundable VAT rates. The relatively lower energy intensity of this sector has led to lower equivalent export VAT non-refund rates. As shown by figure six, the introduction of both four scenarios generate equivalent export non-refundable VAT rates lower than the current rates of the sector and thus would not generate competitiveness problems.

Figure 6. Export non-refundable VAT rates by product of pulp and paper sector: 2011



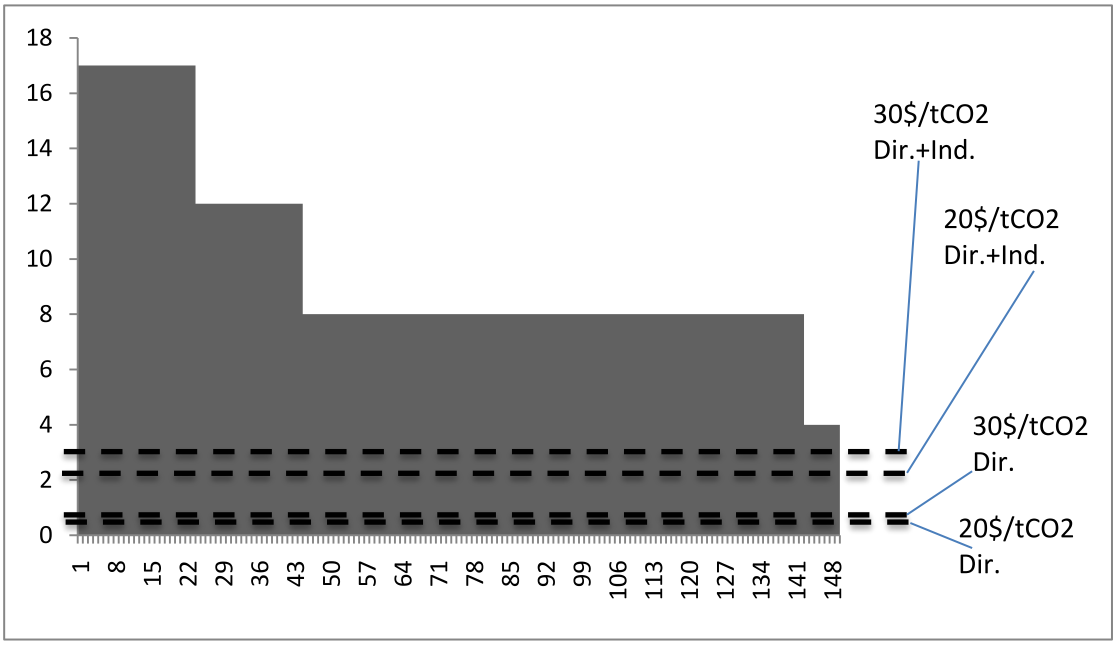
Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.

Rubber:

The export VAT refund rates are low and medium for most of the rubber products in 2011. Similar to pulp and paper sector, the introduction of explicit carbon price(s) would not generate competitiveness problems. As figure seven shows, for all scenarios (20 and 30$/tCO2 with direct or direct+indirect CO2 emissions tax base), the equivalent export non-refundable rates are below the current export non-refundable export rates of all products of rubber sector.

In summary, at product level, the introduction of 20$/tCO2 with direct CO2 emissions tax base would be the most feasible option for introducing an explicit and predictable carbon price on the export of the major energy-intensive sectors studied here.

Figure 7. Export non-refundable VAT rates by product of rubber sector: 2011



Vertical axe: export non-refundable VAT rates (%); horizontal axe: number of products.

2.5 Export carbon price modification

In terms of the determination of the carbon price to be introduced to export, the unique carbon price could be increased, decreased or maintained depending on different purposes and contexts. If domestic carbon price increases, the export carbon price might be reduced in order to maintain the total carbon price that export receives. For example, if the domestic carbon price is implemented from zero to 5$/tCO2 at the time when 20$/tCO2 has already been given on the export, the export carbon price could be reduced to 15$/tCO2 and by consequence, related equivalent export VAT-non refund rates should be modified. Yet this is not necessarily obligatory. The carbon cost dedicated to export may also be maintained when domestic carbon price increases if the objective of reducing the export of energy-intensive products is wished to be achieved more rapidly than the target of curbing domestic expansion of energy-intensive sectors.

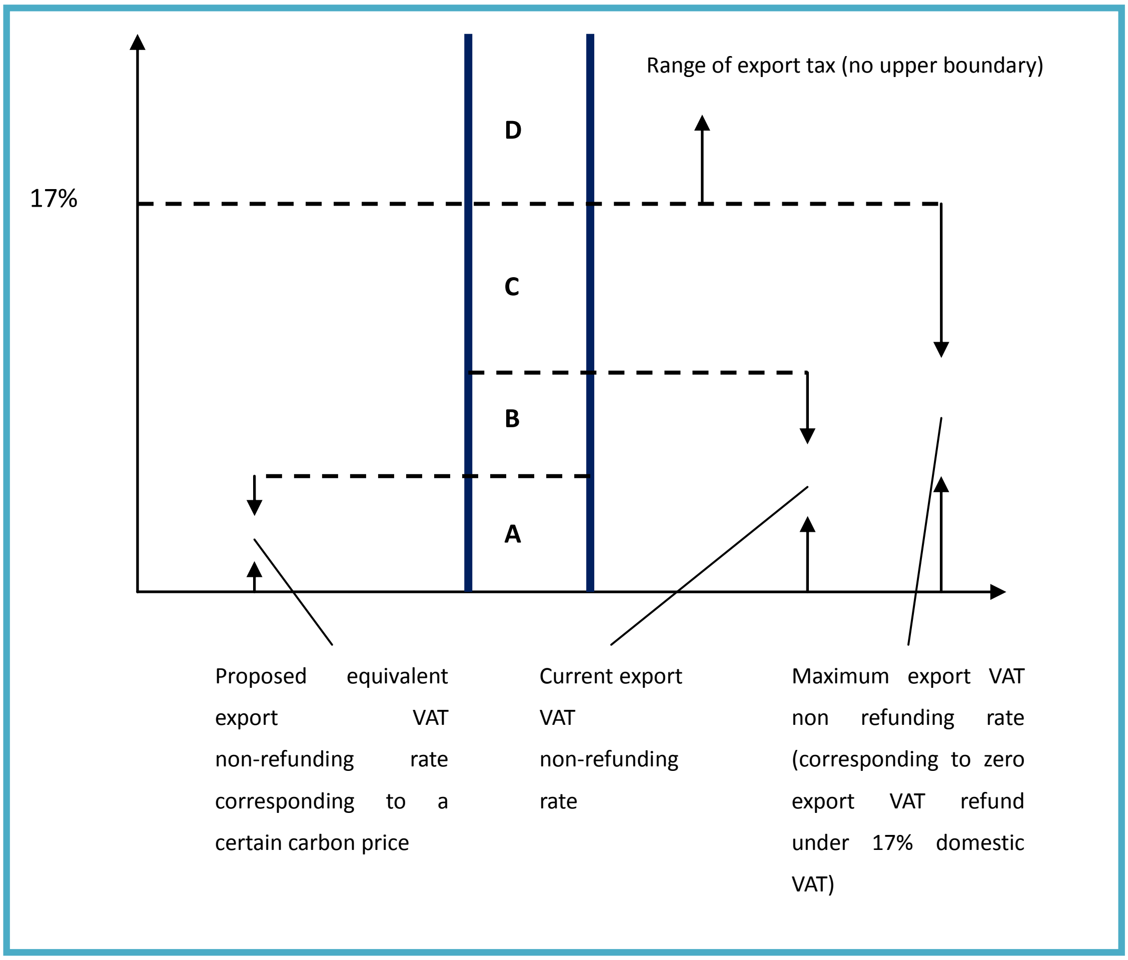
Moreover, if the political willingness intends to tighten the export of energy-intensive products with a major objective of reducing CO2 emissions, the carbon price of export could send a long term signal with an increasing carbon price rate. In such regard, there are three different steps which can be illustrated by Figure eight. As seen, the calculated equivalent export non-refundable VAT rate which corresponds to a specific carbon price for a given sector is lower than the current export VAT non-refunding rate that the sector receives. Therefore, the introduction of an explicit carbon price does not generate any costs on the export of that sector.

1st Step. The first step of carbon price increase does not introduce extra costs on exports as long as it does not overcome the current export VAT non-refunding rate (sum of A and B in Figure eight). In such a case, total export non refundable VAT rate could still vary for other non-climate change reasons as long as the equivalent export VAT non-refunding rate to a certain carbon price is maintained.

2nd Step. For the second step following an increasing carbon price on export, the equivalent export non-refundable VAT rate will be higher than the current export non-refundable VAT rate, thus introducing a real incremental cost on exports. In figure eight, this range is represented by the part “C”. However, this step still leaves room for the use of export VAT non-refunding policy for non-climate change reasons. Similarly to the situation in the first step, as long as the equivalent export non-refundable VAT rate which corresponds to a certain level of carbon price does not reach to 17%, there is still room for the use of export non-refundable VAT policy to deal with non-climate change reasons, although this room may be smaller than what is in the first step.

3rd Step. For the third step, if the export carbon price continues to rise after reaching to the maximum value of 17% (which is the domestic VAT rate), the introduction of an explicit and stable carbon price into export will then require an export tax based on zero export VAT refund policy. In such a case, the use of export non-refundable VAT policy will be totally dedicated to addressing the climate change. For example, if 30$/tCO2 is introduced into chemical sector based on its direct and indirect CO2 emissions, this would require a zero export VAT refund plus an export tax of 5% (See table two). However, export tax could still be increased for non-climate ends in this case. Therefore, for all the three cases, there is total policy flexibility so that the use of EVRRET would not be limited to fighting against climate change.

Figure 8. Illustration of export VAT non-refunding rate modification



2.6 Discussion

2.6.1. The impact of using equivalent export VAT non refunding rates obtained from 2007 data on other years.

We have used the equivalent export VAT non-refunding rates obtained based on 2007 data for the introduction of an explicit carbon cost based on 2011 level. Indeed, the equivalent export VAT non refunding rates, if calculated based on 2011 data, could differ from the results calculated on 2007 data mostly due to the fact that the export CO2 emissions and export value of each sector change among years. This could lead to different equivalent export VAT non-refunding rates by different years. However, the relatively high representativeness of 2007 data which are not impacted by the world economic crisis and the sufficiently adjacent year span between 2007 and 2011 together constitute the most best-available database for such method of introducing an explicit carbon price into the export non-refundable VAT policy.

In practice, it would require a regular benchmark revision on the equivalent export non-refundable VAT rates for each sector for example, each two or three years given that the sectoral export value and CO2 emissions could both change among years.

2.6.2. The choice of export carbon price and energy-intensive sectors

We have selected two carbon prices in this section. This choice is completely arbitrary in terms of precise carbon price level and not totally arbitrary in terms of the range of the price which lays in a comparable level to EU ETS carbon price. However, with the method proposed, we have provided a feasible and comprehensive approach for the policy maker who might choose other carbon prices to calculate equivalent export non-refundable VAT rates for specific products and sectors.

Also, the policy maker's choice of the energy-intensive sector which may submit to such introduction of explicit and stable carbon price could be different to those selected by our study. Chapter Three has provided a detailed sectoral energy/carbon intensity rank and this could be a good and comprehensive reference for policy makers to choose EI sectors. However, as mentioned above, the current data availability has restrained our analysis based on sectoral level. Further studies might be useful for choosing energy- or carbon-intensive sectors once sub-sectoral and/or product CO2 emissions data is accessible.

2.6.3 Results comparison between equivalent export tax and export VAT refund rates

As seen in table two and three above, the equivalent export VAT non-refunding rates are identical to equivalent export tax rates when their rates level is low and differ slightly to each other when the rates level is higher. This is due to the data integration and the approach designed in part 2.1. For example, dividing equation 1 by equation 3 will have

$$0.17 - \mathrm{T}_{\mathrm{i}}^{\mathrm{R,Op}} = 1.17 \times \mathrm{T}_{\mathrm{i}}^{\mathrm{Ex,Op}} \quad (5)$$

Given that the domestic VAT rate (VATi) is 17%. $0.17 - \mathrm{T}_{\mathrm{i}}^{\mathrm{R,Op}}$ as a whole is the equivalent rate of export non-refunding, let $0.17 - \mathrm{T}_{\mathrm{i}}^{\mathrm{R,Op}} = \mathrm{T}_{\mathrm{i}}^{\mathrm{NR,Op}}$, we have

$$\mathrm{T}_{\mathrm{i}}^{\mathrm{NR,Op}} = 1.17 \times \mathrm{T}_{\mathrm{i}}^{\mathrm{Ex,Op}} \quad (6)$$

Therefore, the higher the $\mathrm{T}_{\mathrm{i}}^{\mathrm{Ex,Op}}$, the larger the difference between $\mathrm{T}_{\mathrm{i}}^{\mathrm{Ex,Op}}$ and $\mathrm{T}_{\mathrm{i}}^{\mathrm{NR,Op}}$.

3. Alternative option: making predictable non-refundable export VAT rates for climate purpose

3.1 Method

The option demonstrated above requires creating new export VAT refund rates in order to introduce stable, explicit and unique carbon cost into current export VAT refund policy in China. This might introduce additional administrative complexity in terms of export VAT refund rate management. As table Four shows, the current Chinese export VAT refund rates are composed by seven rates: 0%, 5%, 9%, 13%, 15%, 16% and 17% (which are equivalent to export VAT non-refundable rates of 17%, 12%, 8%, 4%, 1% and 0%, respectively given the 17% domestic VAT rate in China). As seen, the equivalent export VAT non-refunding rates that the first option proposes differ to these rates.

Therefore, another choice could be to designate a fixed percentage of non-refundable VAT on energy-intensive exports for the purpose of addressing climate change. Similarly, such proposal does not hinder further export VAT refund rebates and export taxes for non-climate change ends. In the case of crude steel products that we examined in the previous chapter for instance, the current export VAT refund rate is 0% and the current export tax rate is 25%. Therefore, 12% of non-refunded export VAT under the 17% domestic VAT rate could be defined as fixed export climate change VAT non-refundable rate.

Using the same equations 1-2 of Chapter Four, this rate of VAT non-refund (that is 12% VAT non-refund which is equivalent to 5% export VAT refund with 0% export tax) entails an equivalent export carbon cost of 18, 15 and 4 Euro/tCO2 for crude steel, aluminum and cement, respectively. The rest part of non-refunded VAT and the export tax could be justified for non-climate change purposes and hence vary according to different needs and market conditions (curbing local environmental pollution, price control, etc.). The advantage of such a proposal is that it fixes a predictable and stable export "carbon cost" without depriving other functions of export VAT refund and export tax policy, despite the fact that there is no unique carbon price across sectors. In addition, the introduction of an explicit climate change export VAT non-refunding policy merely requires a division of the current export VAT non-refunding into two categories: a fixed level of export VAT non-refunding dedicated explicitly to climate ends (e.g. the 12% export VAT non-refunding for crude steel mentioned above), and a second variable part of export VAT non-refunding which could be used for non-climate purposes (e.g. the 5% export VAT non-refunding and the 25% export tax for crude steel). As a result, a climate non-refundable export VAT does not generate extra "costs" on current Chinese exports of major energy-intensive products.

3.2 Choice of rates and products

Similar to what has been discussed in part 2.6, the choice of fixed rates of non-refundable export VAT is arbitrary here. The choice of the rate may be different according to different products. For example, a higher rate of non-refundable export VAT for climate ends can be given to primary products such as crude steel, aluminum, etc. and a relatively lower rate of non-refundable export VAT for climate ends can be allocated to EI products having relatively higher value-added. The choice of both energy-intensive products and the fixation of the rate of non-refundable export VAT for climate reason is then of the policy makers. Yet, several principles might be helpful for decision making:

A. If the carbon intensity of a product can be measured thanks to available data (such as crude steel in our case), the determination of the rate of non-refundable export VAT for climate change reasons might be based on whether a certain rate could generate a comparable carbon price (for example, 15-25$/tCO2). Therefore, 12% of non-refundable export VAT could be pertinent for crude steel while not generating real incremental costs on their export.

B. If the carbon intensity of a product is not available so far, the sectoral energy-intensity calculated in Chapter Four could be a second-best reference. For example, based on the result of table four, a rate of non-refundable export VAT of 8% can be given to Iron&steel and basic chemical sectors, 4% for non-metallic product sectors and 2% for petrochemical, non-ferrous metal, pulp&paper and rubber sectors and 1% for chemical fibre sector. This generates an equivalent carbon price range of 15-30$/tCO2 (which is also a comparable area with EU ETS carbon price) and does not engender real incremental cost at sectoral level. Based on table 4, this proposed choice of rates and sectors will not generate any incremental cost for almost all products.

3.3 Case discussion: cement

Our method which uses sectoral CO2 emissions data has shown that for non-metallic product sector, the introduction of 20$/tCO2 based on sector direct CO2 emissions would not generate additional cost for all products (which include cement) in this sector. However, as we have demonstrated in Chapter Six, if calculated at product level, the current export VAT zero refund policy on cement would not generate a EU ETS comparable carbon price. This is due to the relatively lower product value-added and higher CO2 emissions of cement. Therefore, if we use the equivalent export non-refundable VAT rate obtained at sectoral level for cement product, this would not lessen the competitiveness problem (such a situation may also be true for other similar products, such a lime, clinker, etc.). For such products where related data is available, there would be further export taxes in order to ensure the explicit export carbon price that EVRRET could entail. For instance, a higher (and comparable) carbon price (for example 20$/tCO2 here) could be applied on cement export which will require setting a high export tax of 50% together with zero export VAT refund according to the method shown in Chapter Six. However, if the 50% export tax rate for cement export is considered unfeasible (cf. export tax rates have reached to 100%

for fertilizers by periods in recent years), the second-best proposal of this section could ensure a predictable and explicit carbon price for cement, although such a price could not totally lessen the carbon leakage impact in theory.

4. Timelines of implementation

As demonstrated, both options of introducing a carbon price or costs into EVRRET are highly feasible in general. Table five gives the suggested implementation timeline. The year 2012 could serve as a preparation buffer for determining methodologies, selecting sectors, carbon price(s) and making inter-ministerial coordination. The Climate Change Department of NDRC should thus lead the coordination work with Department of Taxation of MOF and the State and local Administration of Taxation. The export carbon pricing policy is proposed to be introduced in the beginning of 2013 together with the 2013 Custom Tariffs of Imports and Exports. The publication of a joint circular of these ministries could ascertain the functioning of the export carbon pricing policy. Followed by the implementation, a benchmark revision would be necessary in 2015 or 2016 in order to examine the equivalent rates of non-refundable export VAT. Also, the industrial process CO2 emissions should be accounted as emission base for calculating equivalent rates of non-refundable export VAT when available. Finally, general modification could be made once the domestic carbon pricing policy is implemented. In addition, if export carbon price increases, central-local government coordination might be necessary taking account that the increasing export carbon cost might impact the revenue generated by exports of EI products from local provinces.

Table 5. Timeline of export carbon pricing policy implementation and revision

<table>
<tr><th></th><th>2012-13</th><th>2013-14</th><th>2015-16</th><th>20XX</th></tr>
<tr><td>Export carbon pricing policy</td><td>Determine approach; Sector/product and carbon price selection and calculation; Prepare related administrative procedures</td><td>Implementation</td><td>First period of benchmark revision; Possible additive industrial process CO2 emission data</td><td>Modification/revision based on national wide domestic carbon pricing policies implementation</td></tr>
<tr><td>Domestic carbon pricing policies</td><td colspan="2">ETS and/or carbon tax pilot programs</td><td colspan="2">National wide implementation.</td></tr>
</table>

5. Conclusion

This chapter has provided an approach to improve the transparency and comprehensiveness of climate policies in China. It shows that the introduction of a unique, stable and explicit carbon cost into export VAT refund rebate, particularly at 20$/tCO2, is preferable to export taxes given competitiveness and WTO concerns. Three determinants make the introduction of a unique carbon cost into the export VAT refund rebate policy feasible in the short term. First, such introduction does not require further reduction in the current level of export VAT refund rates (except for the basic chemical sector) and would generate little industrial resistance. Second, it leaves policy flexibility for further reduction or modification of the export VAT refund rate level, as long as the maximal export VAT refund rate that the carbon cost generates to each sector is respected. Third, the administrative procedures of introducing such an approach are relatively simple. It requires the authorization of the State Council, but does not need further approval at the People's Congress where the implementation of new laws is usually debated. Specifically, this may be done by publishing a circular by related ministries, such as the National Development and Reform Commission, the Ministry of Finance and the State Administration of Taxation.

Moreover, there are several issues that deserve being highlighted.

(1) Export carbon price on energy-intensive sectors as a transition measure. The approach discussed in this chapter is a second best solution in terms of economic efficiency to combat climate change in China. A more effective measure is undoubtedly to implement a domestic carbon tax or cap and trade system of CO2 emission quotas. However, as Chapter Five discussed, such measures usually require implementing new laws that could not be adopted in the short term. Moreover, China still declares itself to be a developing country and favours economic development. The domestic carbon tax or cap and trade system could be expected more in the mid and long term. Therefore, the export carbon taxation that this paper proposes could serve as a transitional measure until the implementation of a domestic carbon tax or cap and trade system. Moreover, the tax base of direct and indirect CO2 emissions ensures further export carbon tax rate adjustment when the domestic rate of carbon tax increases. For example, if domestic carbon price increases to 10$/tCO2, the export carbon price will be reduced by 10$/tCO2 in order to stabilise the total export carbon price at a constant level. Certainly, if process CO2 emissions are also taxed at domestic level, this will require expanding the export carbon tax base to take the process CO2 emissions of the export into account.

(2) Relation with the legalization of export restrictive measures on climate change grounds. The approach proposed by this chapter will, to a certain degree, place a burden on the customs taxation system by setting various ad valorem export tax or export VAT refund rebate rates. It may be argued that the actual legalization of export restrictive measures for climate change purposes may be sufficient as a transitional measure instead of setting divergent ad valorem rates for different sectors and products. In such a case, an alternative method is provided by this chapter which aims only to stabilise a part of the rate of export non-refundable VAT for climate change concerns without requiring setting new rates for export VAT refund policy. However, the slightly higher implementation efforts for the first option that this chapter presents could be compensated by the importance of stabilizing a carbon cost signal in an explicit and comprehensive way. This leaves the choice to the policy maker.

(3) Implication for the EU ETS under carbon leakage concerns. China is one of the major concerns for carbon leakage and competitiveness issues both economically and politically being debated in the EU. The proposal of providing an explicit and stable carbon price on China's export of energy-intensive sectors could be considered as genuine climate policies and could contribute to the attenuation of the carbon leakage effect and therefore present an opportunity for the EU to increase and accelerate the scale of quota auctioning under the EU ETS. According to the definition of carbon price used in this chapter, the CO2 emissions from industrial processes are not taken as the carbon price (tax) base. This does not necessarily discredit the proposal for ameliorating EVRRET policies as a genuine climate policy in terms of the stable and explicit carbon price. However, concerning the carbon leakage effect which could be significant on a few industrial sectors such as cement, steel and aluminum, etc., this does reduce the effectiveness of using such measure to allege the leakage for certain sectors, for example the cement sector. According to Chapter Six, the equivalent carbon price that the EVRRET generated on the export of cement is equal to roughly 5$/tCO2 (3 euro/tCO2). In order to introduce a unique and explicit carbon price, for example 20$/tCO2, an export tax of 50% based on zero export VAT refund should be required on cement.

Finally, this chapter does not demonstrate the degree of emission reduction effectiveness of the export carbon pricing policy, which is another criterion when judging the climate genuineness of a policy beside the explicit carbon price. Such issue will be treated in the following chapter.

References:

Chen, C.-H., Mai. C.-C., Yu., H.-C., 2006. The effect of export tax rebates on export performance: Theory and evidence from China, *China Economic Review*, 17(2), pp.226-235.

General Administration of Customs of China, 2007. 2007 Import and export tariff of the People's Republic of China, China Customs Press, Beijing.

State Administration of Taxation of China, various years, www.chinatax.gov.cn

Chapter Seven. The contributions of an export carbon tax in China

1. Introduction

In Chapter Five, we have demonstrated the lack of explicit, unique, stable and predictable carbon price in the export VAT refund rebate and export tax (EVRRET) policies on energy-intensive sectors, although EVRRET have been announced for climate change ends by the government. In Chapter Six, in the light of providing a comprehensive export carbon pricing policy both for domestic low carbon development and lessening the carbon leakage issue, thus consolidating global climate actions, we have proposed to introduce an explicit carbon price into the EVRRET which would require fixing a part of export non-refundable VAT rate for climate change ends. The advantage of such method is that this introduction of an explicit carbon price would not change the current rates of export non-refundable VAT for most of the energy-intensive sectors. However, the final rates of non-refundable VAT (or VAT refund rates) and/or export tax of a product could still vary as a result of rates modification for uses other than climate change. This does not deny the explicit carbon price signal that the proposal of Chapter Six ensures but could lead to different CO2 emissions reductions due to net rates change of EVRRET.

In such a case, this chapter provides an alternative of introducing explicit (and comparable) carbon prices on China's export. It aims to study the impact and feasibility of implementing an export carbon tax (ECT) in China. So far, there exist some studies focusing on the feasibility of an border carbon measure in developed countries (for example, Messerlin, 2010; Quick, 2008; Bhagwati and Mavroidis, 2007; Ismer and Neuhoff, 2007) while little has focused on the feasibility of an export carbon measure on developing countries. ECT can serve both China's domestic low carbon economy (LCE) development and to lessen carbon leakage and competitiveness problems.

This chapter is organized as follows. Part Two presents the method of introducing the export carbon price into the SI-CGE model; Part Three shows data and policy scenarios; Part Four examines the results obtained from the SIC-GE model; Part Five discuss the WTO-compatibility of export tax with a particular focus on the conundrum of using export tax in China; Part Six concludes and provides policy recommendations.

2. Methods

2.1 Converting the unique carbon price into ad valorem sectoral ECT rate

This chapter assumes that a unique carbon price is allocated to exports based on the direct CO_2 emissions generated by each sector's exports. The reason that only direct emissions are taxed is due to the nature of environmental taxation, which only taxes direct pollutant emissions[66]. The direct CO_2 emissions for each sector i E_i is estimated by equation (1)

$$E_i = \sum_j E_{ij} \times C_j \times rb_j \qquad (1)$$

where E_{ij} is the jth type fossil fuel consumption of sector i, C_j is the carbon content of the jth fossil fuel and rb_j the combustion rate of the jth fossil fuel.

The direct CO_2 emissions E_i^{ex} due to export is estimated by equation (2)

$$E_i^{ex} = E_i \times VEX_i / VTOT_i \quad (2)$$

where VEX_i is the gross value of the exported good i and $VTOT_i$ is the gross value (total output) of the same sector i.

The sector ad valorem ECT rates AVT_i were obtained by equation (3)

$$AVT_i = E_i^{ex} \times T / VEX_i \qquad (3)$$

where T is the unique export carbon tax rate. So far, the industrial process CO2 emissions data are not publicly available in China. Export carbon tax base may need to include such emissions when available.

2.2 Integrating AVT into the model

According to equation (20) of Chapter Two, t_i^{EX} can be written by

$$t_i^{EX} = \frac{\Delta T_i}{T_i} \times 100 \qquad (4)$$

where ΔT_i is the change of tax level in sector i, which in our case corresponds to the implementation of an ECT, T_i is the power of the tax level of sector i. Let $\Delta T_i = AVT_i$, then the export carbon tax can be inputted into the SICGE model.

3. Data and scenarios

It should be reminded that data from 2007 have been used in this analysis as at the time of the study these figures were the most up to date available.

3.1 Fossil fuel consumption by sector

The total sectoral consumption (physical quantity) of different fossil fuels is available from the 2008 China Energy Statistical Yearbook (ESY) (See Chapter Two).

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[66] Also, this is due to the fact that the impact of the selected carbon price on China's export is small (as will be demonstrated by this chapter) therefore whether the tax basis is only direct CO2 emissions or direct+indirect CO2 emissions like the previous chapter will generate very little differences on final results.

3.2 Gross value of export and total output

The gross value of sectoral export and total output can be obtained from the 2007 input-output table of the Chinese economy. Its competitive form, which does not distinguish between domestic and imported inputs, is sufficient for this paper, given that direct CO_2 emissions from fossil fuel combustion for exports is generated by both imported and domestic inputs.

3.3 Sector division

China's Statistical Yearbook divides the Chinese economy into 44 sectors based on the National Industries Classification (GB/T 4754-2002) standard. We keep the same sector division based on this 44-sector style to the sector division used in Chapter Three.

3.4 Scenarios

3.4.1 Reference scenario

The baseline scenario (known as S0) is given for the period of 2007-2015 based on Mai (2006). The SICGE model is recalibrated using *China's External Trade Indices* for the period of 2003-2008 published by the General Administration of Customs of China. Major macroeconomic variables under S0 are given in table one. The export growth rates of major sectors are given in table two. The impact of the world economic crisis on the Chinese economy can be seen in this table for 2008 and 2009, with a recovery starting in 2010.

Table 1. Major macroeconomic variables under the baseline scenario (%)

	2007	2008	2009	2010	2011-2015
GDP growth (1)	14.2	9.5	9.2	10.3	9.0
Consumption growth	10.6	8.8	10.8	5.5	9.4
Capital formation growth	13.9	10.6	28.7	11.4	9.9
Export growth	19.9	8.4	-19.4	16.7	8.4
Import growth	15.8	7.7	-10	15.6	8.5
CPI growth	4.4	5.9	-0.7	2.2	2.9
Employment growth	0.8	0.6	0.6	0.6	0.6

Note: (1) Growth rate is given under comparable price

Table 2. Growth rate of the export of major sectors under the baseline scenario (%)

	2007	2008	2009	2010	2011-2015
Basic chemicals	23.0	-1.0	-39.2	15.3	7.0
Textile and clothing	12.0	6.2	-10.3	6.7	5.8

Rubber and products	26.6	-2.3	-45.7	11.1	6.0
Plastic and products	7.3	-0.2	-20	12.8	10.0
Non-ferrous metal	-4.7	-5.3	-53.5	12.1	4.7
Glass	25.4	12.0	-22	12.6	8.6
Manufacture of toys	19.7	-2.3	-44.4	4.2	5.8
Manufacture of electrical equipments	20.1	14.9	11.7	14.8	12.9
Machinery	34.0	12.0	-37.2	14.7	11.3

3.4.2 Policy Scenarios

An ECT with a comparable rate of 200 yuan/tCO_2 (roughly 30$/t$CO_2$ or 22 euro/tCO_2) is assumed to be implemented on all export products based on their direct emissions (service and building sectors not included) given in the 2007 baseline scenario. This chapter analyses three policy scenarios that are distinguished according to the way in which ECT revenue is redistributed:

Scenario S1: the revenue is not redistributed and pooled into the general central budget. This scenario could be considered as the most feasible option given that, for almost all existing taxes, China does not yet earmark tax revenues for specific uses.

Scenario S2: As shown below, investment is one of the most affected variables under S1. Under scenario S2, by keeping the fiscal neutrality, the tax revenue is redistributed to reduce the sales tax for investment goods in order to examine whether and how investment and related aspects are affected.

Scenario S3: Given that one of China's central objectives is to stimulate domestic consumption more than investment and export, the revenue is redistributed to reduce the sales tax to promote consumption by assuring fiscal neutrality.

A scenario involving the redistribution of tax revenue to exports is not analyzed in this chapter. Such redistribution would improve the welfare effect by causing a lower reduction in exports, relative to S1, from energy-intensive sectors. However, it would also result in a lower reduction of direct CO_2 emissions from exports, compared to the other scenarios. Such a scenario would therefore work against China's central objective, which is to reduce the export of energy-intensive sectors. Moreover, the current fiscal regime makes it difficult to determine whether the tax revenue should be redistributed to producers or to exporters in China.

4. Results

4.1 Equivalent sector AVT and sectoral CO_2 emissions

Table three shows the sector AVT and direct sectoral CO_2 emissions in 2007, based on 2007 trade data and equation (5).

Table 3. Sectoral export direct CO_2 emissions under the baseline scenario and AVT (selected major sectors)

Sectors	Sector AVT (%)	E_i^{ex} (Mn tons)
Agriculture	1.4	0.425
Mining and washing of coal	3.9	3.301
Extraction of petroleum and natural gas	1.2	1.438
Mining and processing of ferrous metal ores	0.0	0.330
Mining and processing of non-ferrous metal ores	0.1	0.196
Mining of other ores	0.4	0.596
Manufacture of foods, beverages and tobacco	2.4	0.248
Manufacture of textile	13.3	0.324
Manufacture of wearing and leather	2.3	0.080
Lumber and furniture	1.6	0.130
Manufacture of paper and paper products	2.1	1.313
Printing, reproduction of recording media	0.1	0.062
Manufacture of articles for culture, education and sport activity	0.6	0.067
Processing of petroleum, coking, processing of nuclear fuel	10.0	2.607
Manufacture of raw chemical materials and chemical products	39.8	2.281
Manufacture of medicines	1.0	0.286
Manufacture of chemical fibers	1.0	0.767
Manufacture of rubber	2.3	0.322
Manufacture of plastics	0.7	0.098
Manufacture of non-metallic mineral products	20.0	2.695
Smelting and pressing of ferrous metals	96.8	5.254
Smelting and pressing of non-ferrous metals	4.3	0.587
Manufacture of metal products	2.0	0.111
Manufacture of machinery	5.3	0.186
Manufacture of transport equipment	2.0	0.122
Manufacture of electrical machinery and equipment	1.4	0.042
Manufacture of communication equipment,	3.3	0.031

computers and other electronic equipment		
Manufacture of measuring instruments and machinery for cultural activity and office work	0.9	0.057
Other manufacturing	0.9	0.129

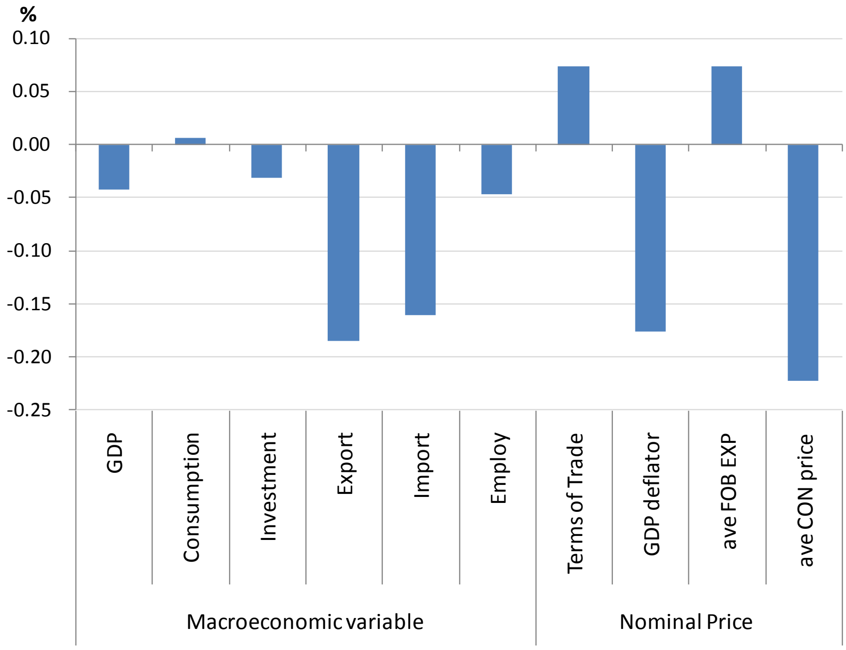
4.2 Impact of ECT

This section provides a detailed analysis of the S1 scenario results, rather than all three scenarios, given that similar analytical methods were applied in each case. Unless specifically indicated, the reference scenario used throughout this section is S0. Detailed examination of the reliability of the results, based on the quantitative analysis framework of the Back of the Envelope Model (Dixon and Rimmer, 2002), is given in Appendix A.

4.2.1 Macroeconomic impact

According to the model, implementing ECT at 200yuan/tCO_2 is equal to an average ad valorem export tax rate impact of 0.44%, generating 41.6 billion Yuan as tax revenue. Related results are given in figure one. A part of the impact of an export carbon tax is absorbed by the increase of the export FOB price, which will increase by 0.07% relative to S0. Another part of the impact will be absorbed by decreasing the production price of domestic products. However, under the general equilibrium theoretical mechanism, the producer price of different demands (such as export, household & government consumption, investment and intermediate input, etc.) for the same commodity will be identical. Therefore, under scenario S1 the GDP deflator and the average consumer price decreased respectively by 0.18% and 0.22%. The export demand decreased by 0.185% following an increase of the export FOB price of commodities. This would create unemployment (-0.05%) in the short term due to the presence of unskilled rural-urban migrant workers and labor market segmentation. Total GDP decreased slightly by 0.043% as a net effect of the unemployment, the decrease in welfare due to ECT implementation and the short term rigidity of technology and capital stocks. As components of GDP expenditure, household & government consumption, capital formation and imports experienced changes of 0.006%, -0.03% and -0.16% respectively.

Figure 1. Macroeconomic impact of ECT in China

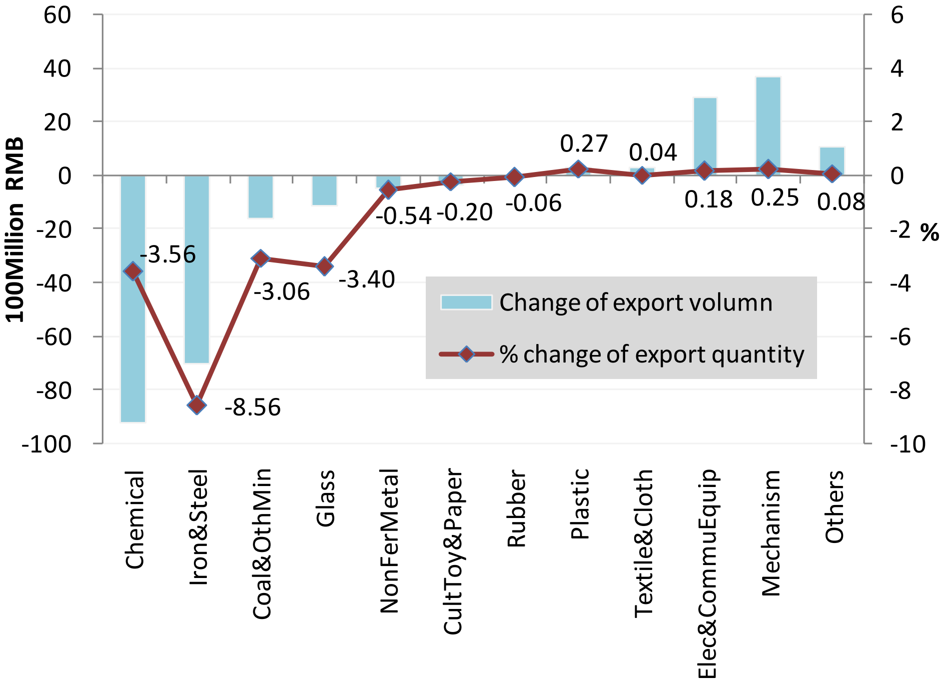


Source: SIC-GE

4.2.2 Export structural effect

The structural effect on export is shown in figure 2. We have further regrouped the sectors into twelve sectors in order to make our presentation easier to read without losing details on sectors significantly affected. For energy-intensive sectors, due to the method used in this paper for taxing the direct CO_2 emissions of exports, fossil-fuel-intensive sectors showed a significant decrease in exports (iron and steel, chemical, coal mining product and glass sectors) while the impact on exports from some electricity intensive sectors was relatively slight (non-ferrous metal sector). Exports increased from labor-intensive sectors and those with higher value-added and technology contents (plastic, mechanism and electric & communication equipment sectors). This is due to the depreciation of the real exchange rate (-0.18%) which compensated for the volume effect of the export carbon tax on these products (-0.06%) and reduced their purchaser price on the international market.

Figure 2. Structural effect of export carbon tax on China's export



Source: SIC-GE

4.2.3 CO_2 emissions

A decrease in the export of major energy-intensive sectors is the major source of the reduction of CO_2 emissions (see table four). As a result, the ECT reduced around 3.6% of direct CO_2 emissions (10Mt) due to exports. The total national CO2 emission would reduce by 0.25% (15 MtCO2), which is due to the indirect emission reduction effect that export entails.

Table 4. CO_2 emissions reduction from export

	Baseline scenario emissions ($MtCO_2$)	CO_2 emissions reduction ($MtCO_2$)	CO_2 emissions reduction/base line emissions (%)
Chemical	49.8	-1.77	-3.60
Iron&Steel	96.8	-8.29	-9.38
Coal&OthMin	5.6	-0.17	-3.25
Glass	3.08	-0.10	-3.59
NonFerMetal	4.3	-0.02	-0.55
CultToy&Paper	4.3	-0.01	-0.12
Rubber	2.3	0.00	-0.04
Plastic	0.7	0.00	0.35
Textile&Cloth	15.6	0.01	0.07
Elec&CommuEquip	4.2	0.01	0.21
Mechanism	10.7	0.03	0.29

Others	84.9	0.07	-0.12
Total	282.3	-10.26	-3.6

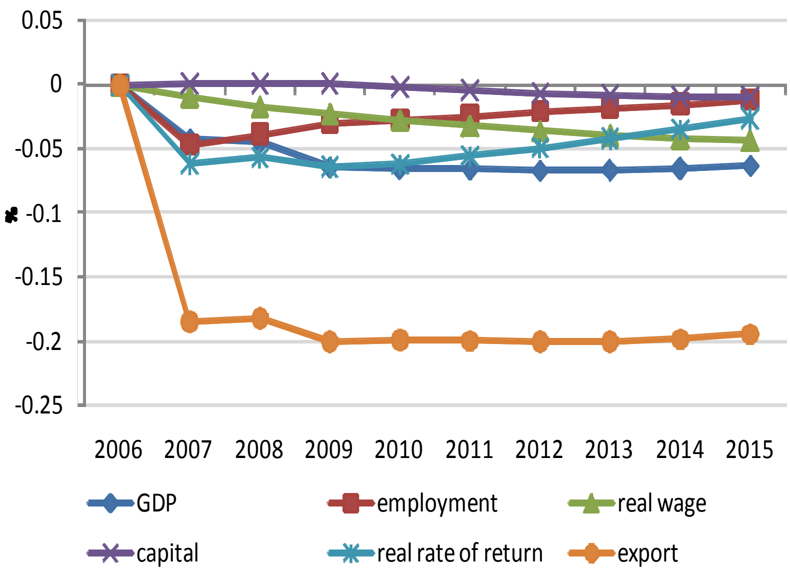
Source: SIC-GE.

4.2.4 Long-term impact

Figure three shows the long-term impact of an ECT on major economic indicators. The technology improvement is exogenous in this study. Employment is shown to be negatively affected due to the assumption of a rigid real wage in the short term. However, in the long term, the higher supply relative to demand would engender a reduction of real wages and therefore the demand for labor would recover toward its initial level. In precise terms, employment was shown to reduce by 0.05% in 2007 and by 0.02% in 2012. Investment decreased in the long term and the capital stock decreased by 0.01% in 2012. This led to a readjustment of the real rate of return of capital. The cumulative impact of primary production factors, labor and capital, lead to an impact of ECT on GDP that remains stable from 2009 at -0.07%, and because the export tax rate is fixed, the negative impact on export will remain at -0.20%.

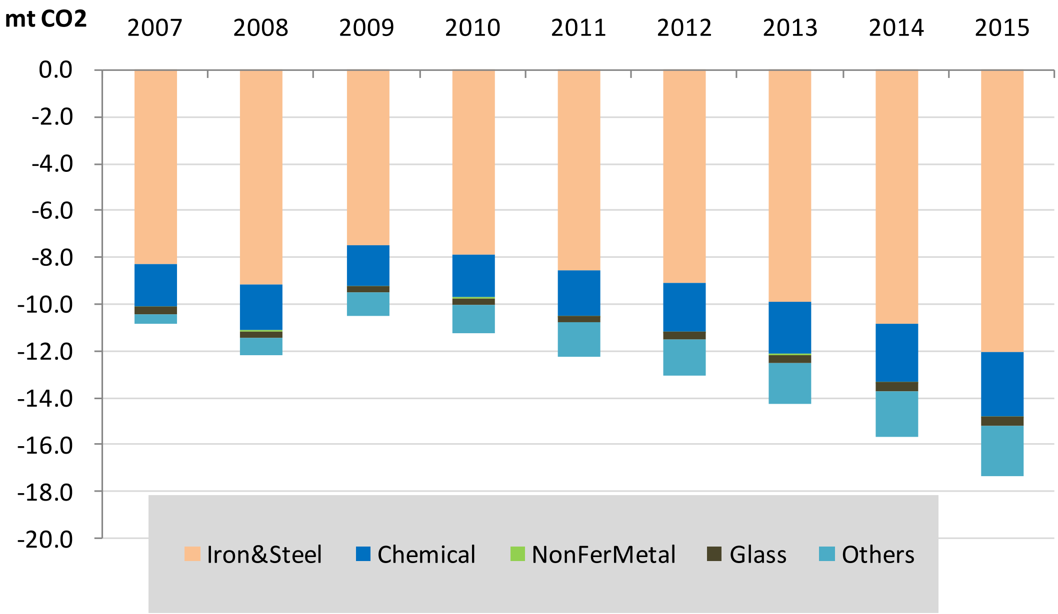
Figure four illustrates the impact of an ECT on long-term CO_2 emissions reduction from export. As shown, total direct CO_2 emissions from export decreased continuously following ECT implementation. The upward trend in total direct CO_2 emissions reduction from export in 2009 is principally due to the impact of the economic crisis. Similarly to the findings of the short-term analysis in Chapter Four, iron and steel, chemical, non-ferrous metal and glass sectors were the major contributors to the long-term reduction in CO_2 emissions from Chinese export.

Figure 3. Long-term impact on major economic indicators (%)



Source: SIC-GE.

Figure 4. Long-term export CO_2 emissions reduction (Mt CO2)



Source: SIC-GE.

4.3 Comparison of the different policy scenarios

4.3.1 Macroeconomic impact

Table five shows the macroeconomic impacts of an ECT for all three scenarios. Under S2, the investment goods price decreased by 0.31% which is just 0.05% lower than the same price decrease under S1. The decrease in the nominal rate of return of capital differs only slightly between S1 and S2. As a result, there was a smaller decrease in the real rate of return of capital in S2 than in S1, relative to S0, leading to a less negative impact on investment (-0.023%). The impacts on GDP for S1 (-0.043%) and S2 (-0.041%) are also similar while the impact on final consumption has changed from positive to negative. This is due to GDP expenditure identity; however, a more likely explanation may be related to the relative changes in the general nominal prices of investment goods, final consumption and the GDP deflator. For instance, in S2, the general nominal price of investment goods decreased by a larger amount than in S1, relative to the price of consumption, which could be due to a more attractive investment demand in S2 among the items of GDP expenditure identity. Therefore, more national revenue is distributed to capital formation than to final consumption. However, this effect would run counter to China's willingness to stimulate consumption in the coming years.

Under S3, the consumption price decreased by 0.28%, a greater decrease than in S1. This stimulated an increase in household consumption (0.052%) that was higher than in S1 and S2. The negative impact of ECT on the nominal rental of capital is also less than in S1 and S2. This led to a lesser decrease, compared to S1, of both the real rate of return of capital and the investment demand. Finally, compared to S1 and S2, S3 had a smaller decrease in GDP, which resulted from a greater increase of consumption and a lesser decrease in investment.

Table 5 Scenario comparison of ECT impact on macroeconomic variables (%)

	S1	S2	S3
GDP	-0.043	-0.041	-0.021
Consumption	0.006	-0.006	0.052
Investment	-0.031	-0.008	-0.009
Export	-0.185	-0.186	-0.192
Import	-0.160	-0.154	-0.139
Employment	-0.047	-0.043	0.000
Price of household consumption	-0.223	-0.228	-0.276
Nominal rate of return of capital	-0.323	-0.317	-0.265
Price of investment goods	-0.262	-0.309	-0.254
GDP deflator	-0.176	-0.196	-0.188
Terms of trade	0.073	0.073	0.076
Real rate of return of capital	-0.061	-0.008	-0.012

Source: SIC-GE.

4.3.2 Export structure changes

While ECT impact on exports was identical in all three scenarios, the tax revenue was not directly redistributed to the exporting sectors and thus the impact on the export structure change remained slightly different under the three policy scenarios (see Table 6).

Table 6. Scenario comparison of sectoral export changes (%)

	S1	S2	S3
Chemical	-3.56	-3.56	-3.58
Iron&Steel	-8.56	-8.57	-8.57
Coal&OthMin	-3.06	-3.07	-3.07
Glass	-3.40	-3.41	-3.41
NonFerMetal	-0.54	-0.54	-0.55
CultToy&Paper	-0.20	-0.20	-0.21
Rubber	-0.06	-0.06	-0.05
Plastic	0.27	0.27	0.26
Textile&Cloth	0.04	0.04	0.04
Elec&CommuEquip	0.18	0.18	0.17
Mechanism	0.25	0.24	0.24

Others	0.08	0.09	0.07

Source: SIC-GE.

4.3.3 CO_2 emission reductions from exports

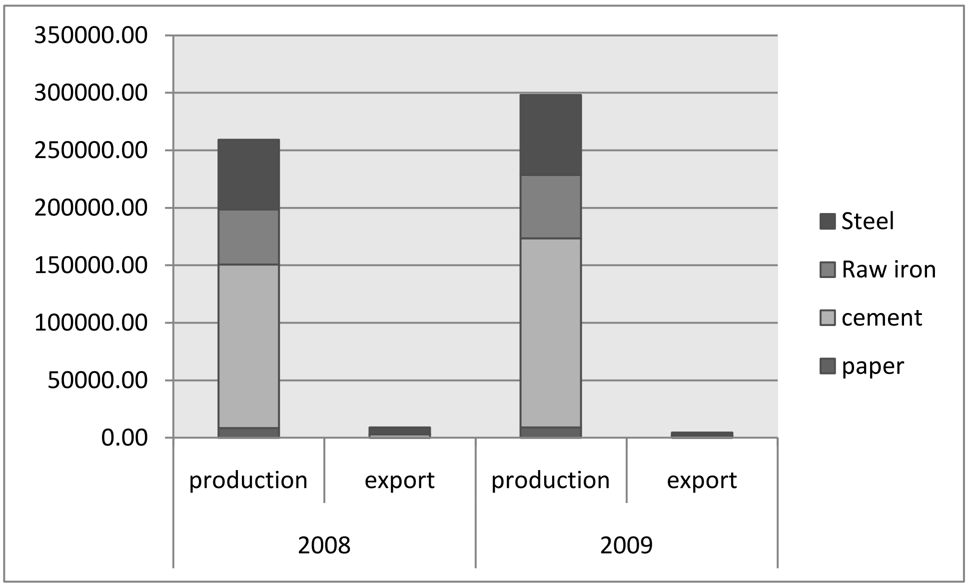
Directly determined by sectoral export, the sectoral export emissions reductions also differ only slightly across each scenario (Table 7). This can also be show by figure five based on real statistical data. As seen, the export of major energy-intensive products only accounts a very small share of their domestic production.

Table 7. Scenario comparison of CO_2 emissions from exports ($MtCO_2$)

	S1	S2	S3
Chemical	-1.81	-1.81	-1.82
Iron&Steel	-8.29	-8.30	-8.30
Coal&OthMin	-0.26	-0.26	-0.26
NonFerMetal	-0.02	-0.02	-0.02
Textile&Cloth	-0.01	-0.01	-0.01
Glass	-0.29	-0.29	-0.29
Rubber	0.00	0.00	0.00
CultToy&Paper	0.00	0.00	0.00
Plastic	0.00	0.00	0.00
Mechanism	0.02	0.02	0.02
Elec&CommuEquip	0.01	0.01	0.01
Others	-0.18	-0.18	-0.20
Total	-10.84	-10.85	-10.87

Source: SIC-GE.

Figure 5. Domestic production and export of selected energy-intensive products in China: 2008-2009 (10,000 ton)



Source: 2010 Statistical Yearbook of China.

4.4 Sensitivity test

To test sensitivity, the ECT rate was doubled from 200 Yuan/t CO_2 to 400 Yuan/t CO_2. Following the same framework as table 5, table 8 compares the macroeconomic variables of the three scenarios. As shown, at this higher carbon price S3 demonstrated significant advantages and could therefore be confirmed as the optimal policy scenario of the three studied in this paper.

Table 8. Scenario comparison of macroeconomic variables at an ECT of 400 Yuan/ton CO_2 (%)

	S1	S2	S3
GDP	-0.09	-0.08	-0.04
Consumption	0.02	-0.01	0.11
Investment	-0.06	-0.01	-0.01
Export	-0.36	-0.37	-0.38
Import	-0.32	-0.31	-0.28
Employment	-0.09	-0.08	0.00
Price of household consumption	-0.44	-0.45	-0.54
Nominal rate of return of capital	-0.63	-0.61	-0.51
Price of investment goods	-0.52	-0.61	-0.50
GDP deflator	-0.34	-0.38	-0.36
Terms of trade	0.14	0.15	0.15
Real rate of return of capital	-0.11	0.00	-0.01

4.5 Discussion

4.5. 1 Choice of policy scenarios

We have showed that the implementation of a 200 Yuan/ton CO_2 ECT would contribute to China's own demand for development while also lessening carbon leakage concerns. An ECT generates very little decrease in GDP and reduces exports from major energy intensive sectors. The redistribution of ECT revenue towards the stimulation of consumption (S3) is the best choice among the scenarios studied in this paper. However, China's tax revenue redistribution function is still under reform and has not yet been adopted for existing taxes. Taking the slight welfare differences among scenarios into account, the non revenue redistribution (S1) scenario could also be considered as a politically feasible option.

4.5.2 Choice of sectors receiving export carbon tax

The export carbon tax is designed to be implemented on all exports in China. Yet in reality, this might not be necessary. The export carbon tax could also be imposed only on energy-intensive sectors. In such a case, the choice of sectors and carbon price rates are similar to discussions in the previous chapter, for example, the export carbon tax could be imposed on iron and steel, basic chemical, glass and non-ferrous metal sectors. This could significantly reduce the management cost and complexity and also reduce the probability of WTO disputes by export tax.

4.5.3 Product export carbon tax rates

Finally, in terms of calculating export carbon tax for products and the modification of the ECT rate when domestic carbon price increases, the mechanisms are the similar to what we discussed in Chapter Seven. When domestic carbon price increases, the export carbon price could be reduced in order to maintain total carbon price on the export. In the long term, the increasing domestic price will gradually catch up with the total export carbon price and finally replace it.

5. WTO compatibility with export carbon tax and EU-China policy convergence

5.1 Export tax under the WTO

Compared to other trade instruments, the export tax is less frequently discussed at the WTO and the necessary legislation is incomplete (Karapinar, 2010). The use of export tax can generally be considered feasible according to GATT Art XI para. 1, as long as the tax is non-discriminatory. Art XIII para.1 of GATT clearly states that "*[n]o prohibition or restriction shall be applied by any contracting party…on the exportation of any product destined for the territory of any other contracting party, unless…the exportation of the like product to all third countries is similarly prohibited or restricted*".

It is, however, the elimination of export taxes that is commonly combined into the "WTO-plus" obligations for new entrant country members on their accession to the WTO (for example, China, Mongolia, Saudi Arabia, Ukraine and Vietnam). In the Protocol of Accession of China (WT/L/432), it is clearly stated in Art. 11, para. 3, that "*China shall eliminate all taxes and charges applied to exports unless specifically provided for in Annex 6 of this Protocol or applied in conformity with the provisions of Article VIII of the GATT 1994*." This "Annex 6" includes 84 products (HS 8-digit), mainly steel and other non-ferrous metal products. However, the note at the end of Annex 6 leaves flexibility for further export tax implementation: "*China confirmed that the tariff levels included in this Annex are maximum levels which will not be exceeded. China confirmed furthermore that it would not increase the presently applied rates, except under exceptional circumstances. If such circumstances occurred, China would consult with affected members prior to increasing applied tariffs with a view to finding a mutually acceptable solution.*" Export carbon tax with the intention of addressing climate change, if properly designed and involve consultations with China's major trading partners, should therefore qualify as WTO compatible.

5.2 China's export tax disputes at the WTO and the dilemma of using export tax

However, the EU, US and Mexico's attack in 2009 on the use of export tax policy on raw materials in China has brought complexity and uncertainties on the use of export tax. The concerns of Europe are two-fold: first, China does not stick to its Protocol of Accession by increasing the export duties of and/or introducing additional products to the list of Annex 6 without initial notification process; second, the question doubts whether similar measures are implemented at domestic level of China so that Chinese domestic firms are in equal condition of competition with EU-located firms. However, the use of non discriminative export tax is generally allowed in the WTO and the existence of similar domestic policies is not usually a problem. Even the EU has proclaimed that "[m]ost countries, to date, have imposed trade restrictions on commodities or other less processed products" and "[t]his is logical since the measures such as export taxes usually are intended to promote higher value-added activities" (European Commission, 2007).

Therefore, the major argument and concern is the Protocol of Accession which limits the use of export tax, even though the tax is used for environmental concerns in China. Facing the dispute raised by EU, US and Mexico, Chinese government has defended the use of export tax for resource and environmental protection[67]. This argument is unfortunately not an exception for using export tax according to the Protocol of Accession which limits all kinds of use of export tax that is not agreed based on common consultancy. In the case of climate change, this seems to create a dilemma for our proposal of the export carbon tax: the latter can reduce carbon leakage but will not be WTO-compatible due to the constraints set by the Protocol of Accession.

5.3 Confusions of EU trade policy on China's coke export

One of the materials that are listed in the WTO dispute is coke which carries a 40% export tax and does not benefit from a VAT refund in China. As we know, coke production is very carbon intensive and environmentally damaging. The EVRRET that China has adopted and explicitly designated for climate change mitigation goals within its National Program on Climate Change could be an efficient way to prevent carbon leakage and thus contribute to global greenhouse-gas emissions reduction in the coke sector. Herein lays the first confusion that EU policy generates: in a trade view, the export tax on coke is not "acceptable" while in a climate view, the use of export tax could be welcomed in order to curb carbon leakage and competitiveness problems.

Second, the confusion that EU's trade policy on Chinese coke lays on the use of anti-dumping on Chinese coke. On September 19, 2007, the EU decided to impose an anti-dumping duty on Chinese coke for six months after receiving the complaints of

[67] See "Ministry of Commerce of China: the restrictions on raw materials are WTO-compatible", June 25, 2009, available at http://news.xinhuanet.com/fortune/2009-06/25/content_11597290.htm (in Chinese)

three domestic coke producers (Regulation 1071/2007). Comparing the current EU complaint on the export restriction of coke, the EU policy coherence over time can be questioned. The lack of policy coalition on coke may leave the impression that China is never right on its price: a low price liberated at the border reflects a dumping motive while a high price which is designed for environmental purposes generates trade distortions. Without discussing the juridical pertinence of EU policies, such confusions would not contribute to ensuring the functioning of export carbon pricing policies in China.

5.4 Convergence on the use of export tax on energy-intensive products

The above mentioned WTO dispute majorly focused on resource products. However, by comparing the 2009 export tariff and the list supplied in Annex 6 of China's Accession Protocol to the WTO, several products such as steel and aluminum could also trigger further WTO disputes given that the use of export tax on such products is not "allowed" by the Protocol of Accession. For example, as table nine shows, for the iron and steel sector (HS chapter 72), only 14 primary iron and steel products (HS-8) are enlisted by the Annex 6 of China's Protocol of Accession, while the number of products (HS 8) of iron and steel sector which received temporary export tax in 2009 in China attains to 67[68], among which half are final steel products which could be competing EU steel products. This is a probable reason that such products are not submitted to dispute in the WTO. However, positively interpreted, this could reflect a willingness of the EU on China's use of EVRRET policies on energy-intensive products of which the leakage effect might be significant (such as steel and aluminum). As Barrett (2010) pointed, trade is bilateral and trade instruments can be more easily founded by a strategy of reciprocity. This provides therefore an opportunity of reaching common agreements on the use of export carbon pricing policy in China between the EU and China on energy-intensive products, particularly on sectors which generate major CO2 emission reduction once a carbon price is imposed, for example, as both this chapter and Chapter Three showed, iron and steel, basic chemical, glass and non-ferrous metal sectors.

Table 9. Export tax rates fixed in China's Accession Protocol (AP) to the WTO and temporary export tax rates in 2009 in China of Iron and Steel sector (HS-72)

	Number of products (HS-8)	Export tax rates
AP	17	20%, 25%, 40%
2009 Export tax	50 (which include the 17 products mentioned in AP)	5%, 10%, 15%, 20%, 25%, 40%

Source: AP, Custom House of China

6. Conclusion

We have demonstrated in this chapter that the feasibility of implementing export carbon pricing policy, even at a level which is comparable with EU ETS, seems to be

[68] Similar situation can be found in 2010 and 2011 where the number of steel products receiving export tax is much higher than what is written in the Accession Protocol of China.

very high. The introduction of an export carbon price would generate little negative macroeconomic impact on GDP but would restructure dramatically the Chinese export toward greener contents. This corresponds perfectly to China's LCE development strategy. In terms of CO2 emissions reduction, the total emission reduction in 2007 could be 15MtCO2, which is higher than the reduction of direct CO2 emission due to export (10 MtCO2) as a result of indirect effects that export entails. However, each reduction represents negligible share with regard to total national CO2 emissions. This is principally due to the dominant domestic consumption of share of major carbon and energy intensive products in China.

The implementation of an export carbon tax could either cover all exports or be imposed merely on major energy-intensive products and/or sectors such as steel, aluminum, basic chemicals, etc. given that such sectors could be the principal contributors to CO2 emissions reduction. Similar to the introduction of a carbon price into EVRRET showed in the previous chapter, the implementation of the export carbon tax could be authorized by publishing a regulation while it does not necessarily require introducing a new law.

At the global level, the use of export carbon tax could also be a potential contribution for the EU as well as other Annex I countries where more stringent climate policies are under preparation. The current use of export taxes on energy-intensive products such as aluminum and steel where the leakage concern is significant does not provoke WTO disputes, although the use of export tax on such products goes against what the Accession Protocol to the WTO of China defines. In this regard, the design of an explicit and predictable export carbon pricing policy in China could contribute to reaching to an **EU-China agreement** on the use of border carbon measures. First, EU and China can identify products on which the border carbon pricing could be of common interests in terms of climate change. Second, for products of which the use of border carbon pricing measures would generate disputes (for example, coke here which is both a raw material and a carbon- and energy-intensive product), EU and China would effectuate a mid- or long-term strategy and/or initiative to negotiate in order to reach an agreement of a proper use of border pricing measures on such products.

Two options of an EU-China agreement of border carbon pricing measures are available:

First, only the use of export carbon pricing is adopted on the export of Chinese border. Under this option, EU and China should reach to stabilizing the use of export carbon price within a fixed horizon with similar benchmark revision mechanisms discussed in Chapter Six.

Second, both import carbon pricing on the EU border and the export carbon pricing policy on Chinese export could be used. In this option, the use of import border carbon measures in Europe must disconnect to the criteria of whether a country makes sufficient climate efforts (cf. section 5.3 of General Introduction).

The merits of reaching to such an agreement are at least four-fold:

First, it ensures a comprehensive and predictable climate policy for export restructuring and therefore for domestic LCE development of China;

Second, it contributes to lessening carbon leakage and competitiveness problem in a comprehensive manner;

Third, it could contribute to tightening climate policy in EU (for example, to accelerate the stringency of quota auctions at EU ETS) given that China is the most cited country by EU industries in the literature of carbon leakage;

Finally and most importantly, it could give a positive political example on North-South cooperation for tackling carbon leakage and competitiveness questions and could involve more participation both of developed and developing countries of using border carbon measures in a cooperative way. Carbon leakage therefore would be much less a negative blockage in the context of consolidating international efforts for addressing the climate change.

Yet still, major CO2 emissions reduction potential resides domestically. The export carbon tax serves mostly as a transitional measure before that domestic carbon price reaches to a significant and effective level in China.

References:

Barrett, S., 2010. Climate change and international trade: lessons on their linkage from international environments agreements, Paper presented at TAIT conference, June 16-18, 2010

Bhagwati, J., Mavroidis, P.C., 2007. Is action against US exports for failure to sign Kyoto Protocol WTO-legal?, *World Trade Review*, 6(2), pp.299-310.

Dixon, P.B., Rimmer, M.T., 2002. *Dynamic General Equilibrium Modeling for Forecasting and Policy*, North-Holland, pp.88, 243.

European Union Commission, 2007. State of play of work on trade restrictions affecting access to raw materials, Available from http://trade.ec.europa.eu/doclib/docs/2008/february/tradoc_137761.pdf

Ismer, R., Heuhoff, K., 2007. Border tax adjustment: A feasible way to support stringent emissions trading, *European Journal of Law and Economics*, 24, pp.137-164.

Karapinar, K., 2010. Export restrictions on natural resources: policy options and opportunities for Africa, World Trade Institute, University of Bern, Switzerland. http://www.wti.org/fileadmin/user_upload/nccr-trade.ch/news/TRAPCA%20Paper%20(Submitted1711)_BK.pdf

Messerlin, P., 2010. Climate change and trade: from mutual destruction to mutual support, World Bank Policy Research Working Paper No.5378.

Quick, R., 2008. "Border tax adjustment" in the context of emission trading: climate protection or "naked" protectionism, *Global Trade and Customs Journal*, 3, pp.163-175.

Appendix A. The simplified framework for explaining the SIC-GE model's results

Non-modelers and policy makers tend to view most CGE models as "black boxes" which produce results that are not always easily comprehended. This appendix follows the work of Dixon and Rimmer (2002) and builds a simplified framework to illustrate and justify the results obtained using the SICGE model. For simplicity, the macroeconomic results for S1 are used as a reference.

A.1 Impact on nominal price variables

A.1.1 Impact on nominal price of export

For simplicity, the following illustration assumes that a country produces just one good for domestic use and export. It also assumes that only one good is imported for intermediate input, investment and consumption usage, but it is not exported. Equations A1-A3 illustrate the framework by which domestic industries readjust their export prices after the implementation of an ECT in order to maintain international competitiveness,

$$\mathrm{d_{ex}} = -\varepsilon \times \mathrm{p_{FOB}} \qquad \text{(A1)}$$

$$\mathrm{s_{ex}} = \epsilon' \times \mathrm{p_{pret}} \qquad \text{(A2)}$$

$$\mathrm{p_{FOB}} = \mathrm{p_{pret}} + \mathrm{p4t} \quad \text{(A3)}$$

where d_{ex} is the percentage change in the exported good's international demand (For example, the percentage change of a variable D is given by a lower case d, where $\mathrm{d} = \frac{\Delta \mathrm{D}}{\mathrm{D}} \times 100$), ε>0 denotes the absolute value of price elasticity of export demand and p_{FOB} the percentage change of export FOB price. It is assumed that the international demand would be directly affected by the FOB price of export, which would therefore substitute the consumer price of the exported good on the international market. The reason for this assumption is that the ECT would have little effect on the margins of international trade, so the change in FOB price of the export good would be totally passed through to the consumer price of the export good on the international market. Finally, s_{ex} is the percentage change of export supply, ϵ' is its price elasticity, p_{pret} is the factory gate price of the export good and p4t, given in the percentage form of power, is the export tax change after ECT implementation. In this way, the domestic margin between the factory gate price and the FOB price is omitted for simplicity.

By equalizing the export supply and demand, it can be stated that

$$\mathrm{p_{pret}} = -\varepsilon \times \mathrm{p4t}/(\epsilon' + \varepsilon) \quad \text{(A4)}$$

which illustrates the impact of an ECT on a domestic product's factory gate price. In the real world, a large number of export goods belong to a buyer's market and therefore have relatively higher supply price elasticity. In addition, an important share of China's export is composed of processing trade and therefore has relatively lower supply price elasticity. In general, the percentage decrease of the factory gate price of the export good could be considered as lower than p4t.

According to the SICGE model, the implementation of an ECT could generate 41.6 billion yuan in tax revenue, which equals 0.44% as an average export tax rate, which leads to an export FOB price increase of 0.07% compared to S0. Taking the average price elasticity on Chinese exports (ε) which is 2.5 in the SICGE model, based on equation (A1), the export demand decreased by 0.175%, which is similar to the model's result (-0.185%).

A.1.2 Impact on other nominal price variables

Using the SICGE model, given the assumptions that only one product is produced in one sector and that it has a unitary producer price whether it is for domestic use or export, the export price before tax and the factory gate price of the good for a given sector are therefore identical. The implementation of an ECT would reduce the price of a domestic product for domestic demands as well as the price before tax of export products. As the SICGE model showed, the GDP deflator decreased by 0.176% relative to S0. This also indicates that the real exchange rate depreciates at 0.176%, given that the price of import is not affected by export tax.

A.2 Impact on real economic variables

A.2.1 Impact on profit loss of primary factors

Given the price distortion and labour market segmentation in China, an analytical framework was constructed to interpret the SICGE model results. Based on the GDP expenditure accounting approach, equation (A5) provides the determinant of the GDP deflator,

$$\mathrm{p_{GDP}} = \mathrm{S_C} \times \mathrm{p_C} + \mathrm{S_I} \times \mathrm{p_I} + \mathrm{S_G} \times \mathrm{p_G} + \mathrm{S_{Ex}} \times (\mathrm{p_{Ex}} - \mathrm{p_{Im}}) + (\mathrm{S_{Ex}} - \mathrm{S_{Im}}) \times \mathrm{p_{Im}} \qquad \text{(A5)}$$

where $\mathrm{p_{GDP}}$, $\mathrm{p_C}$, $\mathrm{p_I}$, $\mathrm{p_{Ex}}$ and $\mathrm{p_{Im}}$ denote respectively the percentage change of GDP deflator, average price of consumption, average price of investment, average price of government consumption, average price of export and import. $\mathrm{S_C}$, $\mathrm{S_I}$, $\mathrm{S_G}$, $\mathrm{S_{Ex}}$ and $\mathrm{S_{Im}}$ denote respectively the share to GDP of consumption, investment, government consumption and export and import.

Based on the definition of the marginal product of labour and capital, equations A6 and A7 can be obtained (in percentage form for lower case letters),

$\mathrm{rw} = \mathrm{p_{GDP}} - \mathrm{p_C} + \mathrm{mpl(K, L)} - \mathrm{t}$ (A6)

$\mathrm{q} = \mathrm{p_{GDP}} - \mathrm{p_I} + \mathrm{mpk(K, L)} - \mathrm{t}$ (A7)

where rw is the real wage, q is the real rate of return of capital, $\mathrm{p_{GDP}}$ is the GDP deflator, $\mathrm{p_C}$ is the consumption price, $\mathrm{p_I}$ is the investment average price, mpl and mpk are respectively the marginal product of labour and capital, which are a function of labour L and capital K, and t is the increase of export carbon tax above the general tax level.

Furthermore, in this analysis framework it is assumed that the policy has no impact on the progress of technology in the short term. The percentage change in GDP (lower case letters denote percentage forms) is determined as follows (by omitting the change of tax revenue):

$\mathrm{gdp} = \mathrm{S_L} \times \mathrm{l} + \mathrm{S_K} \times \mathrm{k}$ (A8)

where gdp, l and k are respectively GDP, labour and capital changes; and $\mathrm{S_L}$ and $\mathrm{S_K}$ are respectively the share of labour and capital to GDP.

Equations A5-A8 therefore provide the results analysis framework for the short-term impact of an ECT on real economic variables. ECT increases the general taxation charge and therefore t>0. Real wage can be considered as rigid in the short term, thus rw=0. Since the import price remains unchanged and the export FOB price increases after the ECT implementation, it can be written that $\mathrm{p_{Ex}} - \mathrm{p_{Im}}$>0. Note that the impact mechanism on the price of consumption and investment is similar, their price change in percentage forms could also be said to be identical. According to (A5), the GDP deflator decreases by a smaller amount than the consumption and investment prices, thus $\mathrm{p_{GDP}} - \mathrm{p_C} > 0$ and $\mathrm{p_{GDP}} - \mathrm{p_I} > 0$. However, as an induced effect, these changes should be inferior to the tax change, so $\mathrm{p_{GDP}} - \mathrm{p_C} - \mathrm{t} < 0$ and $\mathrm{p_{GDP}} - \mathrm{p_I} - \mathrm{t} < 0$.

According to (A6), mpl(K, L)>0 means that the marginal product of labour increases after the implementation of an ECT. This would lead to a decrease in employment, which the SICGE model gives as -0.05%. The relative reduction of employment would cause a reduction in the marginal product of capital and, according to (A7), it can be stated that q<0. The SICGE model finds the real rate of return of capital to be -0.061%. Capital remains unchanged in the short term, therefore, according to (A8), GDP reduction correlates to the labour changes. The simplified system obtained a GDP reduction of 0.023%, which differs to the SICGE model's result of 0.043%. This could be explained by the absence of tax impact (see equation (A8)) in the simplified analysis framework.

A.2.2 Estimation of GDP when taking tax revenue into account

According to **A.2.1,** the GDP decrease not only includes the loss of profit of primary factor, but also the loss of net welfare. This tax effect can be illustrated in the following simple partial equilibrium framework. In figure A1, it is assumed that export tax was not implemented at first where the export level is Ex’ and related export price is p’. Following the implementation of an export carbon tax, the export was reduced to Ex’’ with an export price increasing to p’’. The net welfare lost $\Delta\mathrm{WelfLost}$ therefore can be written as

$$\Delta\mathrm{WelfLost} = 0.5 \times (\mathrm{EX}^{'} - \mathrm{EX}") \times (\mathrm{P}'' - \mathrm{P}') \qquad \text{(A9)}$$

Its contribution to GDP decrease, referred to as CONTax, can be obtained by

$$\mathrm{CONTax} = \frac{\Delta\mathrm{WelfLost}}{\mathrm{GDP}} \times 100 = 0.5 \times \frac{\mathrm{EX}^{'}}{\mathrm{GDP}} \times \mathrm{ex} \times \Delta\mathrm{CTaxRate} \qquad \text{(A10)}$$

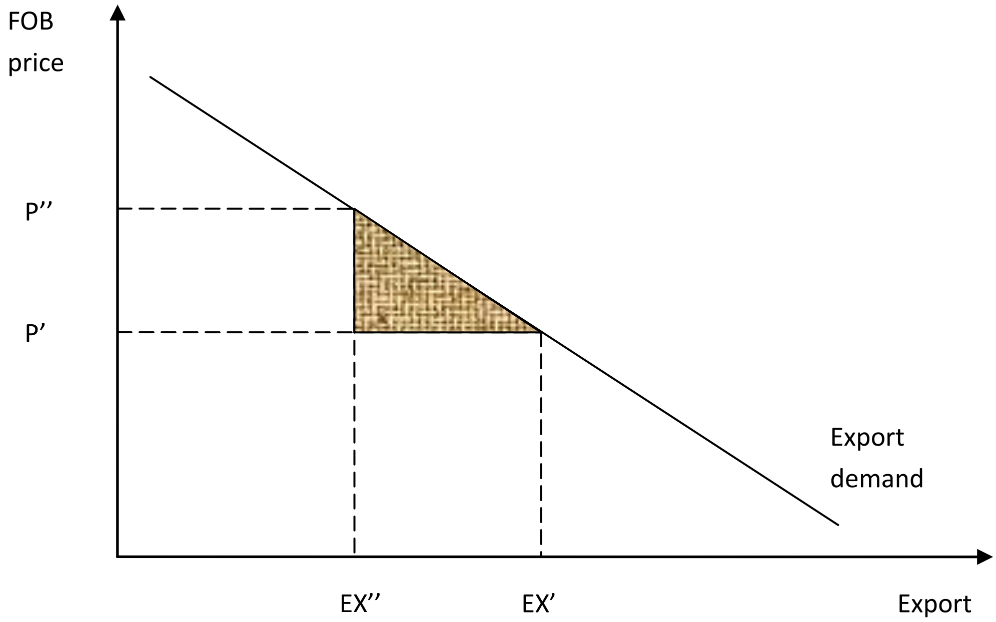
where Ex’ and GDP are, respectively, the export amount and the GDP prior to ECT implementation, in 2007 the ratio of $\frac{\mathrm{EX}^{'}}{\mathrm{GDP}}$ was 0.36. The percentage change of export ex is 0.185. $\Delta\mathrm{CTaxRate}$ is the average tax burden of a carbon export tax on total export, which is 0.44%. By putting this data into (A10), the contribution of the GDP to the decrease in net welfare is found to be 0.015%. If this decrease is combined with the negative growth in GDP obtained in equation A8 (-0.023%), then a figure of -0.038% is obtained as the total GDP decrease following ECT implementation, based on this simplified analysis framework. This figure is close to the actual SICGE result (-0.043%).

B.2.3 Impact on GDP expenditure items

The impact of an ECT on household consumption is determined by the consumption price and GDP deflator. According to equation (A5), the household consumption price decreased to a greater extent than the GDP deflator after the implementation of an export carbon tax, which means that consumer goods would become relatively cheaper and therefore that the export carbon tax would trigger a positive effect on household consumption. The SICGE model gives a slight increase of 0.006%, compared to the baseline scenario, for household consumption.

In the SICGE model, the investment of year t is determined by the anticipated rate of return of capital in the future, which is obtained based on the real rate of return of capital of year t. According to the model and equation (A7), the real rate of return of capital decreased by 0.061% which results in a reduction of investment compared to the baseline scenario. Despite this, the investment price also decreased according to equation (A5), compensating in part for the investment reduction, for which the final value is -0.031% according to SICGE results. As the import price remained unchanged and the domestic price decreased, import demand decreased by 0.16% compared to the baseline scenario.

Figure B1. Welfare effect of export tax



General Conclusion

Under the urgency of making more global efforts to ensure the two degree target, the consideration since the very beginning of the thesis is that a climate policy should be cost-effective, it should contribute to low carbon development, ameliorate mutual trust and consolidate global climate efforts. Facing both challenges of sustainable and low carbon economy at domestic and of increasing responsibility for its fast CO_2 emissions growth in the world, this thesis studies an option of implementing win-win carbon pricing policies in China.

The thesis first shows that most of the current Chinese policies entailing direct or indirect climate effects are under the form of command-and-control policies. They have made significant contribution to China's low carbon development during the last decade. However, such policies are not usually cost-effective and have received so far very limited recognition by the international community. In particular, the lack of an explicit carbon price has made China a primary target in the debate of carbon leakage and competitiveness problems in a world of unequal carbon prices which would persist with or without an international climate change convention. Although such issues received so far mixed research results and reactions, they generate real impacts in political terms rather than in economic terms: first, they hinder the implementation of more stringent climate policies in developed countries, particularly in Europe where a large scale emissions trading system has already been implemented; second, they risk to generate trade wars as well as equity and fairness debates which can lower the mutual trust between developed and developing countries. Neither leads to the consolidation of climate efforts globally.

The thesis then shows that China is clearly aware of the lack of cost-effectiveness in its climate policies and plans to implement more market-based instruments. Among such policies, carbon pricing policies are the most officially discussed instrument. First, the short-term establishment of an (pilot) emission trading system has been pronounced by senior officials. Second, the research of carbon tax has also been conducted at official level for several years. Third, export VAT rebate and export tax have been implemented massively since 2007 on energy- and carbon-intensive products. While the discussion on carbon pricing lays on their domestic impacts, their contribution at the international level has been discussed in a much less extent in China. Recalling Chinese President Hu Jintao's speech at United Nations in 2009, a climate policy should be "win-win for both developed and developing countries and a win-win for both the interests of individual countries and the common interest of humanity", this leads to the making of the central question of the thesis on whether China can implement a domestic and export differentiated carbon pricing policy. Such policy contributes majorly to domestic low carbon development and can generate positive effects on lessening carbon leakage and competitiveness problems, thus contributing to consolidating global climate efforts.

In order to answer this question, the thesis uses both quantitative and qualitative **methods**. For the quantitative assessment, the use of the SIC-GE model of the State Information of China provides policy simulation and ensures both result accuracy and political credibility at the policy making level. For the qualitative assessment, it contributes to understanding the Chinese context and making complementary studies vis-a-vis the quantitative approach. In particular, author's interview and discussion with senior Chinese officials have confirmed key findings and helped to ameliorate policy recommendations of the thesis. In addition, the thesis provides a very detailed demonstration of Chinese data, its comparability and adjustment in order to obtain comprehensive analytical results and to serve for other studies.

Major results of the thesis are composed by two parts: first, how to ensure a short-term implementation of domestic carbon pricing policy; second, how to introduce an explicit (and comparable) carbon price into China's export, particularly on energy and carbon intensive products.

For the domestic carbon price policy, the thesis first used a short-term impact analysis at sectoral level by using the method which is very comparable and compatible to the method used by the European Commission on determining the sectoral carbon leakage and competitiveness impacts. The finding under this approach confirms the current domestic consensus on the choice of the carbon price rate (10yuan/t CO2, roughly 1 euro/tCO2). Under this rate, the short-term sectoral competitiveness impact can be considered "acceptable" regardless the choice of the threshold above which a sector can be considered "affected" by a carbon price. The thesis then continues to analyze the impact of 100yuan/tCO2 (roughly 11euro/tCO2), a carbon price which is considered "high" under the current Chinese debate by using the same method. With the same criteria of a sector under significant impact of carbon leakage and competitiveness of the European Commission, it finds that nine sectors (majorly energy-intensive industries), representing 13% of total Chinese GDP and 36.9% of total Chinese export (gross value) would be affected, where iron and steel, basic chemical and non-ferrous metal sectors are the most affected given their higher carbon and energy intensity.

The thesis then adopts the SIC-GE model to simulate the policy impact of this high carbon price in order to examine whether there is a case to implement such a price by considering different revenue redistribution methods (to reduce the government deficit, to redistribute to reduce the investment price and consumption price) and electricity price pass-through capacity of carbon cost of the electricity sector (0%, 50% and 100% price pass through to downstream users). It finds that the GDP growth impacts vary from 0.22% to –1.10% among scenarios while the CO2 emissions reduction impacts range between –6.75% to –11.16% (with regard to reference scenario). The electricity sector would be the major emission reduction source, representing more than two thirds of total emissions reduction in all scenarios studied. A carbon price might be allocated to key sectors as electricity, iron and steel sectors etc. instead of being implemented at national wide taking account the administrative cost. Balancing short- and long-term impacts, the scenario with revenue redistribution to reduce investment price can be considered an optimal choice among scenarios studied according to the SIC-GE model.

However, the current Chinese contexts have limited the feasibility of the optimal choice obtained under modeling approaches. First, there is so far no earmarking function in the current fiscal regime. Although a special carbon fund may be created for specific revenue use, the redistribution to reduce consumption and investment prices as designed by the SIC-GE model are politically difficult to apply. Second, there is no clear definition on the form and coverage of the carbon price policy so far in China. Both emission trading system and carbon tax will need further works and require horizontal and vertical coordination. Third, there exist alternative proposals of integrating a carbon price into existing policies such as resource tax, polluting fees (charges). Given the current status of carbon pricing policy in China's administrative agenda, together with uncertainties and potential conflict interests among sectors and institutions, the implementation of an explicit domestic carbon price would hardly be achieved before 2015. In order to ensure a fast implementation, the domestic carbon price level should be low while providing long-term predictability both on price stringency and policy coverage.

A low domestic carbon price would contribute to China's low carbon development and gain China certain degrees of international recognition. However, they cannot lessen the carbon leakage and competitiveness problem, at least as effectively as the theory depicts (since there are always unequal carbon prices). This leads to the second part of the analysis of the thesis. First, the thesis demonstrates that there is no political willingness of exporting energy- and carbon-intensive products in China. To the converse, China aims to restructure its export (as well as its domestic economy) toward higher share of products with higher added value and technology contents. Author's interview has confirmed that the major willingness of current export VAT rebate and export tax policies (in case of zero export VAT refund) on energy- and carbon-intensive products is to curb energy consumption and reduce CO_2 emissions. However, the thesis has also demonstrated that these policies are sometimes used for non-climate-energy purposes and they generally fall short on explicit, stable, predictable and unique carbon price, although most of the implicit carbon prices that these policies generate lay in an comparable or even higher level than EU ETS carbon price. Therefore, such policies can hardly be considered as genuine climate policies although they have been written into Chinese official climate change documents.

Based on China's willingness of using such export restrictive policies for climate change end, the thesis therefore aims to examine if an explicit and even comparable carbon price can be introduced into China's export policies as a transitional measure before domestic carbon price reaches to a similar level. Such tentative is also motivated by the finding that most leakage-sensible products (such as steel, aluminum, cement, etc.) receiving export VAT rebate and/or export tax in China have never generated WTO disputes so far (although some other products such as raw materials do). Therefore, an explicit export carbon price could be highly feasible. It constitutes a comprehensive and cost-effective climate policy both for China's domestic development and for lessening the carbon leakage and competitiveness problems. Two options are proposed by the thesis: first, to integrate a unique carbon price into current export VAT rebate and export tax policies; second, to implement separately an export carbon tax. Either have relative advantages and disadvantages.

For the first option, the thesis finds that the carbon price (20-30$/tCO2) generates specific equivalent export non-refundable VAT rates (which is equal to domestic VAT minus the export VAT refund rate) which are lower than the current export non-refundable VAT rates for most of the energy-intensive products and sectors. This indicates that the introduction of such a carbon price will not entail additional cost on the export of these products (except for some steel and chemical products). These equivalent export non-refundable VAT rates should be declared to correspond to the fixed carbon price (20-30$/tCO2) and be fixed as long as the export carbon price is fixed. Such policy always leaves flexibility for the use of export VAT refund and export tax policies non-climate purposes: total export non-refundable VAT rate for a certain product can vary based on this fixed carbon-pricing-policy-equivalent export non-refundable VAT rate. The advantage of such proposal is that it generates no extra competitiveness problems and does not require making new laws. In addition, such proposal does not generate WTO disputes as long as the refunded VAT is lower than domestic VAT. The disadvantage is that it is incorporated into the general export VAT rebate policy which serves for both climate and non-climate ends, thus being less comprehensive with regard to a direct carbon tax.

For the second option, the thesis proposes to implement directly an export carbon tax and dismiss the climate purpose of the current export VAT rebate and export tax policy. By using SIC-GE model which simulate policy impacts of an export carbon tax at 200yuan/tCO2 (roughly 20euro/tCO2), it confirms the following things: first, such a price generates negligible negative GDP impacts; second, it creates significant export structure effects by decreasing the export of major energy-intensive products (for example, iron and steel sector) and increasing the export of certain products with higher added value (for example, equipment sector); third, it contributes to little national CO2 emissions reduction which conforms to the dominant domestic consumption of major energy-intensive products in China. The advantage of such an option is that it is very explicit and comprehensive. The disadvantage is that it requires making new taxes thus implementing new policies which will generally takes more time. Also, it risks generating WTO dispute on the difference of domestic (low) and export (high) carbon prices, thus requiring international coordination and consultation, particularly with China's major trade partners (the European Union, the US, etc.).

To **summarize**, this thesis proposes to consider a short-term implementation of a domestic and export differentiated carbon pricing policy in China. It is indeed a second-best option given the potential difficulty of reaching to a domestic comparable carbon price in the short term in China. However, the advantage of such an option is that it is a win-win policy among feasible options: first, it sends a clear price signal and contributes to address cost-effectively climate change at domestic in China. A higher and explicit export carbon price corresponds to China's short-term strategy of limiting strictly the export of energy and carbon intensive product, while prioritizing domestic consumption of some of these products which are necessary and indispensable to ensure a rational economic growth. Second, it contributes to lessening the carbon leakage and competitiveness problems particularly in major developed countries as Europe and US and could facilitate further climate policy implementations in such countries. It is true that a comparable carbon price on China's export will not resolve completely the carbon leakage and competitiveness problems (at least theoretically). However, such a policy can provide a pro-active Chinese strategy. It shows an example that a domestic policy in developing countries can be designed to generate a win-win solution both for contributing to domestic development and for strengthening global climate efforts, even based on contentious issues.

Finally, there are some areas which are not treated in this thesis and can lead to important **further researches**. First, this thesis uses national model for policy simulation due to the detailed sectoral data. Global model can be used as a complementary analysis of the impact of carbon pricing policies in China, particularly on global trade and CO_2 emissions. Further model linkage with SIC-GE can also contribute to increasing the accuracy of existing global models. Second, the lack of more detailed energy and CO_2 emission data has limited the accuracy of the thesis. Expansive analysis based on the analytical framework proposed by the thesis may need to be done once the data is available. Third, this thesis has treated but does not discuss in a very detailed manner how a specific carbon pricing policy (for example, an emission trading system) can be implemented. Further studies should proceed based on policy evolution in China. Finally, this thesis does not treat the use of carbon pricing policies in China in terms of international cooperation. This is partially because that the domestic and export differentiated policy is designed to be domestic policy. However, the use of a comparable export carbon price in China at one side and a higher comparable domestic carbon price in the future on the other side, may require international coordination and/or cooperation. Studies focusing on the international aspects of carbon pricing policies, such as policy linkage, coordination and the relation of carbon pricing policies with sectoral approach etc. may be very useful.

General References:

Adams, F.G., Chen, Y., 1996. Skepticism about Chinese GDP growth – The Chinese GDP elasticity of energy consumption, *Journal of Economic and Social Measurement*, 22(4), pp.231-240.

Allais, M., 1943. *A la recherche d'une discipline économique*. Première partie. L'économie pure. Réédité sous le titre : Traité d'économie pure, Imprimerie Nationale, Paris.

Ang, B.W. and S.Y. Lee, 1994. Decomposition of industrial energy consumption – some methodological and application issues, *Energy Economics* 16, pp.83-92.

Ang, B.W. and F. Q. Zhang, 2000. A survey of index decomposition analysis in energy and environmental analysis, *Energy* 25, 1149-1176.

Ang. B.W., 2004. Decomposition analysis for policymaking in energy: which is the preferred method? *Energy Policy* 32: 1131-1139.

Ang. B.W., 2005. The LMDI approach to decomposition analysis: a practical guide. *Energy Policy* 33, 867-871.

Arrow, K., Debreu, G., 1954. Existence of an equilibrium for a competitive economy, *Econometrica* 22, pp.265-290.

Babiker, M.H., Rutherford, T.F., 2005. The economic effects of border measures in sub-global climate agreements, *Energy Journal* 26(4), pp.99-126.

Balassa, B., 1989. Tariff Policy and Taxation in Developing Countries, *World Bank Working Paper*, No. 281.

Barrett, S., 2010. Climate change and international trade: lessons on their linkage from international environments agreements, Paper presented at TAIT conference, June 16-18, 2010.

Baumol, W., J., Oates, W., 1988. *The theory of environmental policy*, 2nd Ed., Cambridge University Press, Cambridge.

Bhagwati, J.N., 2004. *Free Trade Today*, Princeton University Press, Princeton and Oxford.

Bhagwati, J., Mavroidis, P.C., 2007. Is action against US exports for failure to sign Kyoto Protocol WTO-legal?, *World Trade Review*, 6(2), pp.299-310.

Bhagwati, J.N., Panagariya, A., Srinivasan, T.N., 1998. *Lectures on International Trade*, 2nd Eds., The MIT Press.

Böhringer, C., Fischer, C., Rosendahl, K.E., 2010. The global effects of sub-global climate policies, *The B.E. Journal of Economic Analysis & Policy* 10(2), Symposium, Article 13.

Brenner, M, Riddle, M., Boyce, J.K., 2007. A Chinese sky trust? Distributional impact of carbon charges and revenue recycling in China, *Energy Policy* 35, pp.1771-1784.

British Columbia Federation of Labour (BCFED), 2006. Log Export Crisis in British Columbia: A Time to Act, *BCFED Report*.

Cai, Y., 2000. Between state and peasant: local cadres and statistical reporting in rural China, *China Quarterly*, 163, pp.783-805.

Canadian Imperial Bank of Commerce (CIBC) World Markets, 2007. Russian Log Export Tax, *Equity Research Industry Update*, March 13, 2007.

Central Office of the State Council of China, 2004. Guo Fa Ban (2004), No.82. (in Chinese)

Chai, J., Guo J., Wang, S. and K.K. Lai, 2009. Why does energy intensity fluctuate in China? *Energy Policy* 37, pp.5717-5731.

Chang, Y.-C., Wang, N., 2010. Environmental regulations and emissions trading in China, *Energy*

Policy 38, pp.3356-3364.

Chen, C.-H., Mai. C.-C., Yu., H.-C., 2006. The effect of export tax rebates on export performance: Theory and evidence from China, *China Economic Review*, 17(2), pp.226-235.

Chen, H., 2010. Discussion on influence of coal actual calorific value on energy statistics, *Coal Quality Technology*, 2010 (02), pp.48-50. (in Chinese)

Choeun, H., Yoshihisa G., Yujiro, H., 2006. The economics and politics of rice export taxation in Thailand: A historical simulation analysis, 1950-1985, *Journal of Asian Economics*, 17, pp.103-125.

Cong, R.G., Wei, Y.M., 2010. Potential impact of (CET) carbon emissions trading on China's power sector: A perspective from different allowance allocation options, *Energy Policy* 35, pp.3921-3931.

Copeland, B.R., Taylor, M.S., 2009. Trade, tragedy and the commons, *American Economic Review*, 99(3), pp.725-749.

Copeland, B.R., Taylor, M.S., 2005. Free trade and global warming: a trade theory view of the Kyoto Protocol, *Journal of Environmental Economics and Management*, 49(2), pp.205-234.

Copeland, B.R., Taylor, M.S., 2004. Trade, growth and the environment, *Journal of Economic Literature*, 42, pp.7-71.

Copeland, B.R., Taylor, M.S., 2003. *Trade and the environment, theory and evidence*, Princeton University Press, Princeton and Oxford.

Dai, H., Masui, T., Matsuoka, Y., Fujimori, S., 2011. Assessment of China's climate commitment and non-fossil energy plan towards 2020 using hybrid AIM/CGE model, *Energy Policy* 39, pp.2875-2887.

De Boer, Y., 2007. Changements climatiques 2007 : une année décisive, *Liaison Energie Francophonie* 75, pp. 86-90.

Demailly, D., Quirion, P., 2008. European emission trading scheme and competitiveness: a case study on the iron and steel industry, *Energy Economics* 30, pp. 2009-2027.

Devarajan, S., Delfin, G., Maurice, S., Suthiwart-Narueput, S., 1996. The Whys and Why Nots of Export Taxes, *Policy Research Working Paper* 1684, World Bank.

Dixon, P.B., Parmenter, B.R., Sutton, J., and Vincent, D.P., 1982. *ORANI: A Multi-sectoral Model of the Australian Economy*, North-Holland, Amsterdam.

Dixon, P.B., Rimmer, M.T., 2002. Dynamic General Equilibrium Modeling for Forecasting and Policy. North-Holland. P88, 243.

Dong, W., Meng, X., Duan, H., Deng, X., 2011. Low carbon development in energy sector: review, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.59-113. (in Chinese)

European Union Commission, 2008. The raw materials initiative – meeting a critical needs for growth and jobs in Europe, Communication from the Commission to the European Parliament and the Council (2008), http://ec.europa.eu/enterprise/newsroom/cf/document.cfm?action=display&doc_id=894&userservice_id=1&request.id=0.

European Union Commission, 2007. State of play of work on trade restrictions affecting access to raw materials, Available from http://trade.ec.europa.eu/doclib/docs/2008/february/tradoc_137761.pdf

Ecofys*, 2008. Factors underpinning future action – country fact sheets 2008 update.*

Edminster, L.R., 1930. Control of Exports of Raw Materials: An International Problem, *Sage Publications, Inc.* no. 150.

EIA, 2009. 2009 International Energy Outlook, US Energy Information Administration (EIA).

Ekins, P., Barker, T., 2002. Carbon taxes and carbon emissions trading, in Hanley, N., Roberts, C., Eds., *Issues in Environmental Economics*, Blackwell Publishing, pp.75-126.

Ellerman, A.D., Convery, F.K., de Perthuis, C., 2010. *Pricing Carbon. The European Union Emissions Trading Scheme*, Cambridge University Press.

Elliott, J., Foster, I., Kortum, S., Munson, T., Pérez Cervantes F., Weisbach, D., 2010. Trade and carbon taxes, *American Economic Review* 100(2), pp.465-469.

Fan G., Cao J., Yang, H.W., Li, L.L., SU, M., 2009. Economic development and low carbon economy: China and the world, paper prepared for the forum Economic Development and Low Carbon Economy: China and the World, Beijing, Sept. 12, 2009.

Fan, Y., Liao, H., Wei, Y.M., 2007. Can market oriented economic reforms contribute to energy efficiency improvement? Evidence from China, *Energy Policy*, 35, pp.2287-2295.

Food and Agriculture Organisation of the United Nations (FAO), 2008. Policy measures taken by governments to reduce the impact of soaring prices, *Crop prospects and food situation*, FAO: Rome, pp.13-17.

Feng, B.X., Chen, J.R., 2003. Cement sector CO_2 emissions reduction of Taiwan, Fu Jian Environment, 2003 20(01), pp.16-19. (in Chinese)

General Administration of Customs of China, 2007, 2007 Import and export tariff of the People's Republic of China, China Customs Press, Beijing.

Goode, R., George E.L., Ojha, P.D., 1966. Role of Export Taxes in Developing Countries, *Staff Papers-International Monetary Fund* 3, No. 13.

Gros, D., 2009. A border tax to protect the global environment?, *Center for European Policy Studies Working Paper*, Brussels.

Grubb, M., Brewer, T.L., Sato, M., Heilmayr, R., Dora, F., 2009. Climate Policy and Industrial Competitiveness: Ten Insights from Europe on the EU Emissions Trading System. *Climate & Energy Paper Series* 09, Climate Strategies, Cambridge.

Grubb, M., Ward, M., 2009. Comparability of efforts by Annex I countries: an overview of issues, *Climate Strategies Report*, Climate Strategies, Cambridge.

Hamilton, G., 2008. Russian export tax opens log markets for local, *Vancouver Sun*. Friday, May 02, 2008.

Hanh, F., 1984. *Equilibrium and Macroeconomics*, Basil Blackwell, Oxford.

He, D., Zhang, W., 2010. How dependant is the Chinese economy on exports and in what sense has its growth been export-led?, *Journal of Asian Economics*, 21, pp.87-104.

He, J., Deng, J., Su, M., 2010. CO_2 emission from China's energy sector and strategy for its control, *Energy* 2010, pp. 4494-4498.

Heilmayr, R., Bradbury, J.A., 2011. Effective, efficient or equitable: using allowance allocations to mitigate emissions leakage, *Climate Policy*, 11(4), pp.1113-1130.

Hicks, J., 1939. *Value and Capital: An Inquiry into Some Fundamental Principles of Economic Theory*, 2nd Ed., Oxford University Press, New York.

Holz, C.A., 2003a. Deconstructing China's GDP statistics, China Economic Review 15, pp.164-202.

Holz, C.A., 2003b. 'Fast, clear and accurate.' How reliable are Chinese output and economic growth statistics? *China Quarterly*, 173, pp.122-163.

Holz, C.A., 2006. Revisions to China's GDP data following the 2004 economic census: more questions than answers?, available at SSRN: http://papers.ssrn.com/sol3/papers.cfm?abstract_id=904803

Hourcade, J.-C., Demailly, D., Neuhoff, K., Sato, M., 2007. Differentiation and dynamics of EU ETS industrial competitiveness impacts, *Climate Strategies Report*, Climate Strategies, Cambridge

Houser, T., Bradley, R., Staley, B.C., Werksman, J., Heilmayr, R., 2008. *Leveling the Carbon Playing Field: International Competition and US Climate Policy Design*, Peterson Institute for International Economics, Washington D.C.

Hu, M., 2009. The exploration of implementation of emissions trading system in China, *Journal of Service Science and Management* 2009(2), pp. 270-275.

Hu, X., Liu, Q., 2011. Potential role of sectoral approach for carbon emission reduction in international climate mechanism, case study on the iron and steel sector in China, Draft, *Climate Strategies Working Paper* 10 January 2011. http://www.climatestrategies.org/component/reports/category/54/311.html

Hu, Y., 2007. Implementation of voluntary agreements for energy efficiency in China, *Energy Policy*, 35, pp.5541-5548.

Hu, Z., Liu, W., 2009. *CGE model in energy taxation and exchange rates*, Hunan University Press, Hunan. (in Chinese)

IEA, 2009. CO2 emissions from fuel combustion, highlights (2009 Edition), IEA, Paris. Available at http://www.iea.org/co2highlights/CO2highlights.pdf

IPCC, 2007. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Pachauri, R.K. and Reisinger, A. (Eds.), IPCC, Geneva.

IPCC, 2006. *IPCC Guidelines for National Greenhouse Gas Inventories*, Volume 2 Energy, 2006.

Ismer, R., Heuhoff, K., 2007. Border tax adjustment: A feasible way to support stringent emissions trading, *European Journal of Law and Economics*, 24, pp.137-164.

James, G., 1924. British Preferential Export Taxes, *American Economic Association* 1, no. 14.

Jiang, K.J., Hu, X.L., Deng, Y.Y., Zhuang, X., Liu, H., Liu, Q., Zhu, S.L., 2009. Impact of carbon tax and analysis on related issues, in: Hu, X.L., Wang, J.Z., Cen, L.Y., Lei, H.P. (Eds), *2050 China Energy and CO_2 Emissions Report*. Science Press, Beijing, pp. 413-445. (in Chinese)

Jotzo, F., 2011. Comparing the Copenhagen emissions targets, *Crawford School Centre for Climate Economics & Policy Paper No. 1.10*, http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1878905

Kahrl, F., Roland-Holst, D., 2007. Energy and exports in China, *China Economic Review*, 19(4), pp.649-658.

Kaplow, L., Shavell, S., 2002. On the superiority of corrective taxes to quantity regulation, *American Law and Economics Review* 4, pp.1-17.

Karapinar, B., 2010. Export restrictions on natural resources: policy options and opportunities for Africa, World Trade Institute Paper. http://www.wti.org/fileadmin/user_upload/nccr-trade.ch/news/TRAPCA%20Paper%20(Submitted1711)_BK.pdf

Karapinar, B., Haberli, C., Eds, 2010. *Food crisis and the WTO*, Cambridge University Press, Cambridge.

Keidel, A., 2001. China's GDP expenditure accounts, *China Economic Review*, 12(4), pp.355-367.

Kirman, A., 1989. The intrinsic limits of modern economic theory: the emperor has no clothes, *The Economic Journal* 99, pp.126-139.

Koopman, R., Wang, Z., Wei, S.J., 2008. How much of Chinese exports is really made in China? Assessing domestic value-added when processing trade is pervasive. *NBER working paper* 14109.

Krugman, P., 2009. Climate, Trade, Obama, *New York Times*, 29 June, 2009. http://krugman.blogs.nytimes.com/2009/06/29/climate-trade-obama/

Kuik, O., Hofkes, M., 2010. Border adjustment for European emissions trading: Competitiveness and carbon leakage. *Energy Policy*, 38, pp.1741-1748.

Lallement, J., 2000. Prix et équilibre selon Léon Walras, in Béraud, A, Faccarello, G., Eds, *Nouvelle Histoire de la Pensée Economique*, Tome II, La Découverte, Paris, pp.449-497.

Lau, L., Stiglitz, J., 2005. China's alternative to revaluation, Financial Time, 25/04/2005, available at http://www.ft.com/cms/s/0/cb1955ca-b533-11d9-8df4-00000e2511c8.html#axzz1KcGutAJf

Li, H., 2011. Indicators of low carbon development in China, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.355-372. (in Chinese)

Li, Z., 2003. An econometric study on China's economy, energy and environment to the year 2030, *Energy Policy*, 31, pp.1137-1150.

Liang, Q.M., Fan, Y., Wei, Y.M., 2007. Carbon taxation policy in China: how to protect energy-and-trade-intensive sectors? *Journal of Policy Modeling*, 29, pp.311-333.

Liao, H., Wei, Y.M., 2010. China's energy consumption: A perspective from Divisia aggregation approach, *Energy,* 35, pp.28-34.

Liao, H., Fan, Y., Wei, Y.M., 2007. What induced China's energy intensity to fluctuate: 1997-2006?, *Energy Policy*, 35, pp.4640-4649.

Liu, Z., 2007. *China Taxation*, Economic Science Press, Beijing. (in Chinese)

Liu, L.P., 1997. The reconciliation of national GDP estimates with regional ones in China, in Research of methodological issues on national accounts, Department of National Economic Accounting, State Statistical Bureau, Beijing, 1997.

Lohmar, B., Fred, G. 2008. Who Will China Feed?, *Economic Research Service/USDA*, Vol. 6, no. 3, pp.10-15.

Lv, Z.D., Guo, J.E., Xi, Y.M., 2009. Econometric Estimate and Selection on China Energy CES Production Function, *China Population Resources and Environment*, 2009 (04), pp.156-160. (in Chinese)

Ma., H., Oxley, L., Gibson, J., 2009. Substitution possibilities and determinants of energy intensity for China, *Energy Policy*, 37, pp.1793-1804.

Ma, L., 2011. Market structure reorientation and development quality, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.20-28. (in Chinese)

Ma, L., Li, H., 2011. Responsibility of energy saving targets, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.29-37. (in Chinese)

Ma, X., Li, J. and Zhang, Y., 2009. An ineligible question before Copenhagen, the BAU scenario under international negotiation and climate change researches, *International Economic Review* 6 (2009), 5-8. (in Chinese)

Maddison, A., 1998. *Chinese economic performance in the long run*, OECD, Paris.

Mai. Y., 2006. The Chinese Economy From 1997-2015: Developing a Baseline for the MC-HUGE Model. Centre of Policy Studies Monash University Working paper No. G-161.

Mao, R.B., Chen, Q.T., 2008. A Study of Approaches and Methods to Meet China's 20% Energy Efficiency Target for 2010, Science Press, Beijing, 2008. (in Chinese)

Mao, R.F., Fang, M.X., Mai, G.W., 2004. Waste management and CO2 emissions of cement sector, Research of Renewable Energy, 2004(04), pp.32-37. (in Chinese)

Mao, S.L., 2001. CO_2 emissions in cement sector and emission reduction measures, *China Energy* 2001(07), pp.32-37. (in Chinese)

Marshall, D., 2002. Down the Value Chain: The Politics and Economics of Raw Log Exports, *Canadian Centre for Policy Alternatives*, (November 20, 2002): 1-6.

Mathiesen, L., Maestad, O., 2004. Climate policy and the steel industry: achieving global emissions reductions by an incomplete climate agreement, *Energy Journal*, 25(4), pp. 91-114.

McKibbin, W.J., Wilcoxen, P.J., 2002. The role of economics in climate change policy, *Journal of Economic Perspectives* 16 (2), pp. 107-129.

McMillan, M., Horn, K., Rodrik, D., 2003. When Economic Reform Goes Wrong: Cashews in Mozambique, available at http://www.hks.harvard.edu/fs/drodrik/Research%20papers/nuts.pdf

Messerlin, P., 2010. Climate change and trade: from mutual destruction to mutual support, World Bank Policy Research Working Paper No.5378.

Ministry of Environmental Protection of China, www.sepa.gov.cn

Ministry of Finance of China, www.mof.gov.cn

Monjon, S., Quirion, P., 2010. How to design a border adjustment for the European Union Emissions Trading System?. *Energy Policy*, 38, pp.5199-5207.

NBS, 2003. Guo Tong Zi (2003) No.70. (in Chinese)

NBS, 2005a. Guo Tong Zi (2005), No.14. (in Chinese)

NBS, 2005b. Guo Tong Zi (2005) No.20. (in Chinese)

NBS, 2006. Notice on historical data adjustment of GDP in China, available at http://www.stats.gov.cn/tjdt/zygg/sjxdtzgg/t20060109_402370997.htm (in Chinese)

NBS, 2010a. Explanation on 2009 energy consumption of China, available at http://www.stats.gov.cn/tjdt/zygg/sjxdtzgg/t20100812_402664717.htm (in Chinese)

NBS, 2010b. Command from NBS No. 13, available at http://www.stats.gov.cn/tjdt/zygg/gjtjgg/t20100210_402621290.htm (in Chinese)

NBS, 2010c. Command from NBS No. 14, available at http://www.stats.gov.cn/tjdt/zygg/gjtjgg/t20100609_402648686.htm (in Chinese)

National Development and Reform Commission of China (NDRC), 2007, *China's National Climate Change Programme*, available at http://www.ccchina.gov.cn/WebSite/CCChina/UpFile/File188.pdf

Ngan, H.W., 2010. Electricity regulation and electricity market reforms in China, *Energy Policy*, 38, pp.2142-2148.

Niu, H.B., 2007. Concepts on energy consumption statistics, *Zhejiang Statistics*, 2007 (02), pp.32.33. (in Chinese)

OECD, 2000. *China in the global economy, National accounts for China, Sources and methods,* OECD, 2000, Paris.

Office of National Climate Change Coordination Group, 2004. *Initial National Communication of Climate Change,* China Planning Press, Beijing.

Oster, S., Swartz, S., 2010. China disputes IEA data on energy, the Wall Street Journal, July 21,

2010. Available at http://online.wsj.com/article/SB10001424052748703720504575378243321158992.html

Ou, X.M., Zhang, X.L., Chang, S.Y., 2010. Alternative fuel buses currently in use in China: life-cycle fossil energy use, GHG emissions and policy recommendations, *Energy Policy* 38, 406-418.

Oxfam, 2003. Running into the Sand, *Oxfam Briefing Paper 53*, http://www.oxfam.org.uk/resources/policy/trade/downloads/bp53_cancun.pdf.

Pan, J., Zheng, Y., Zhang, A., 2009. Preliminary studies on the impact of low carbon development on employment in China, http://www.china.com.cn/international/txt/2009-12/11/content_19050870.htm (In Chinese)

Parker, E., Thornton, J., 2007. Fiscal Centralisation and Decentralisation in Russia and China, *Comparative Economic Studies*, 49, pp.514-542.

Peng, Z.L., Liu, L.P., Zhao, T.L., Deng, W.P., Lu, Z.P., Shen, Z., Tang, Y.H., 2009. Study on Regional GDP Accounting Pattern of Four Countries, *Statistical Research*, 26 (4), pp.40-43 (in Chinese).

Piermartini, R., 2004. The Role of Export Taxes in the Field of Primary Commodities, *World Trade Organization*, available at, http://www.wto.org/english/res_e/booksp_e/discussion_papers4_e.pdf.

Ponssard, J.-P., Walker, N., 2008. EU emissions trading and the cement sector: a spatial competition analysis, *Climate Policy*, 8(5), pp. 467-493.

Price, L., Sinton, J.E., Worrell, E., Phylipsen, D., Hu, X., Li, J., 2002. Energy use and carbon dioxide emissions from steel production in China, *Energy* 27, pp429-446.

Productivity Commission, 2011. Carbon emission policies in key economies, *Productivity Commission Research Report*, Australian Government.

Puntasen, A., Preedasak, P., 1998. Agriculture in Thailand at the Cross-Road. *ASEAN Economic Bulletin*, Vol. 15, no. 1, pp.90-107.

Quick, R., 2008. "Border tax adjustment" in the context of emission trading: climate protection or "naked" protectionism, *Global Trade and Customs Journal*, 3, pp.163-175.

Rawski, T.G., 2001a. China by the numbers: how reform has affected China's economic statistics, *China Perspective*, 33, pp.25-34.

Rawski, T.G., 2001b. What is happening to China's GDP statistics? *China Economic Review*, 12(4), pp.347-354.

Reinert, E.S., 2008. *How Rich Countries Got Rich…and Why Poor Countries Stay Poor*. Wimbledon Publishing Company and Anthem Press, India.

Reubens, E., 1956. Commodity Trade, Export Taxes and Economic Development, *The Academy of Political Science* 1, no. 71, pp.42-70.

Rogelj, J., Nabel, J., Chen, C., Hare, W., Markmann, K., Meinshausen, M., Schaeffer, M., Macey, K., Höhne, N., 2010. Copenhagen Accord pledges are paltry, Nature 464, pp.1126-1128 (22 April, 2010)

Samuelson, P., 1947. *Foundations of Economic Analysis*, Harvard University Press, Cambridge.

State Administration of Taxation of China, www.chinatax.gov.cn

Sinton, J.E., 2001. Accuracy and reliability of China's energy statistics, *China Economic Review*, 12(4), pp.373-383.

Sinton, J.E., Gridley, D.G., 2001. A guide to China's energy statistics, Lawrence Berkeley National Laboratory, available at http://china.lbl.gov/publications/guide-chinas-energy-statistics

Sinton, J.E., Gridley, D.G., 2000. What goes up: recent trends in China's energy consumption.

Energy Policy, 28, pp.671-687.

State Council Information Office, 2008. *White Paper: China's Policies and Actions on Climate Change*, Beijing.

Stern, N., 2007. *The Economics of Climate Change: The Stern Review*, Cambridge University Press, Cambridge.

Stern, N., 2009. *The Global Deal, Climate Change and the Creation of a New Era of Progress and Prosperity*. Public Affairs, New York.

Su, M., 2009. Analysis on the Implementation of Carbon Tax in China, paper presented at International Symposium on a Carbon Tax, Beijing, Sept. 8, 2009.

Su, M., Fu, Z., Xu, W., Wang, Z., Li, X., Liang, Q., 2009. An analysis of the implementation of the carbon tax in China, *Review of Economic Research*, 2009, 72, pp.2-16. (in Chinese)

Teng, F., Wang, Y., Gu, A., Xu, R., Mcmahon, H., Seligsohn, D., 2009. Mitigation actions in China: Measurement, reporting and verification, WRI working paper. http://pdf.wri.org/working_papers/china_mrv.pdf

Thee, K.W., 2009. The Indonesian wood products industry, *Journal of the Asia Pacific Economy*, 14(2), pp.138-149.

Tietenberg, T.H., 2006. *Emissions Trading. Principles and Practices*, 2nd Ed., Resources for the Future, Washington, DC.

Transparency International, 2011. Ensuring corporate transparency to mitigate climate change, *Policy Position* 2011/02, available at http://www.transparency.ch/de/PDF_files/Newsletter/2011_TI-S_Policy_Position_Climate_change.pdf

Tubiana, L., Wang, X., 2011. La croissance verte, une option pour la Chine?, La Chine au milieu du monde, *AGIR* 46, pp.149-162.

Viner, J., 1926. National Monopolies of Raw Materials, *Council on Foreign Affairs* 4, no. 4, pp.585-600.

Vivideconomics, 2010. The implicit price of carbon in the electricity sector of six major economies, *Vivideconomics Report* prepared for the Climate Institute, 2010.

Voituriez, T., Wang, X., 2011. Getting the carbon price right through climate border measures: a Chinese perspective, *Climate Policy*, 11, pp.1257-1261.

Wang, A., 2010. Could policymaking be based on the conclusion ignoring the related rules and inconsistent with the facts?, available at http://cdm.ccchina.gov.cn/WebSite/CDM/UpFile/File2546.pdf.

Wang, B., 2007. An imbalanced development of coal and electricity industries in China, *Energy Policy*, 35, pp.4959-4968.

Wang, C., 2003. Ph.D thesis of Chinese climate policy simulation and assessment based on dynamic CGE modeling approach, Tsinghua University, Beijing. (in Chinese)

Wang, J., Yan, G., Jiang, K., Liu, L., Yang, J., Ge, C., 2009. The study on China's carbon tax policy to mitigate climate change, *China Environmental Science*, 2009, 29(1), pp.101-105. (in Chinese)

Wang, J.N., Yang, G., Jiang, K.J., 2009. Carbon tax policy study in China, *China Environment and Science*, 2009(01), pp.101-105. (in Chinese)

Wang, X., 2011. On China's energy intensity statistics: toward a comprehensive and transparent indicator, accepted at Energy Policy.

Wang, X., Chen, Y, 2010. Disentangling border carbon tax – an analysis of the EU policy, *Chinese*

Journal of European Studies, 166, pp.44-48. (in Chinese)

Wang, X., Voituriez, T., 2010. China's export tax and export VAT refund rebate on energy-intensive goods and their consequence for climate change. In Soares, C.D., Milne, J.E., Ashiabor, H., Kreiser, L., and Deketelaere, K. (ed), *Critical issues in environmental taxation, International and comparative perspectives,* Vol. VIII, Oxford University Press, New York, pp.408-428.

Wang, X., Li, J.F., Zhang, Y.X., 2011. An analysis on the short-term sectoral competitiveness impact of carbon tax in China, *Energy Policy*, 39, pp.4144-4152.

Wang, X., Zhang, Y., 2010. Difficulties in carbon price making and solutions, *Theoretical Exploration* 2010(03), pp.66-69. (in Chinese)

Wang, X.T., 2010. China to improve GDP calculation methods, China Daily, 30/01/2010. Available at http://www2.chinadaily.com.cn/china/2010-01/30/content_9401838.htm

Wang, Y., Pan, S., 2009. Status and trends of China carbon market under financial crisis, *Economic Theory and Business Management* 2009(11), pp.19-24. (in Chinese)

Warr, P., 2001. Welfare Effects of an Export Tax: Thailand's Rice Premium, *American Journal of Agricultural Economics*, 83(4), pp.902-920.

Weitzman, M.L., 1974. Prices vs quantities, *Review of Economic Studies* 41, pp.477-491.

Wu, G.H., 2009. Nengyuan tongji yu shijie jiegui de jianyi, *Statistics and Decision* 2009 (12), pp.56-58. (in Chinese)

Xu, S., 2004. China's statistical system and resources, *Journal of Government Information*, 30, pp.87-109.

Xu, X.C., 2002. China's GDP accounting, *China Economic Quarterly* (Jing Ji Xue) 2002 Vol. 4, pp.23-36. (in Chinese)

Xu, X.C., 2008. Some differences in GDP measurements between China's practice and 1993 SNA guideline, *China Economic Review* 19, pp.480-488.

Yang, M., 2010. China's energy efficiency target 2010, *Energy Policy* 36, pp.561-570.

Yang, Z., Chen, B., 2010. Regional emission trading in China, *Academic Monthly* 494, pp.44-47. (in Chinese)

Ye, R., von Weizsacker, E.U., 2009. Economic instrument for energy efficiency and the environment, *China Council for International Cooperation on Environment and Development (CCICED) Policy Research Report*, Beijing, 2009.

Yu, M.L., 2010. Xianji nengyuan tongji wenti yu jianyi, *Manager Journal*, 2010 (01), pp.348. (in Chinese)

Yu, T., Zhang, X., Ma, Y., 2010. Strategies of establishing carbon trading in China, *Social Science Journal* 2010(02), pp.90-94. (in Chinese)

Yu, X., 2010. An overview of legislative and institutional approaches to China's energy development, *Energy Policy* 38, pp.2161-2167.

Yu, Y., Ma, L., Song, W., 2011. Low carbon development in manufacturing sector: review, in Qi, Y. (Eds), *Annual review of low carbon development in China*, Science Press, Beijing, pp.114-164. (in Chinese)

Zee, H.H., 2007. Export Taxes in Times of Trade Surpluses. *Journal of International Trade & Economic Development*, 16(2), pp.137-157.

Zhang, Y., 2010. Supply-side structural effect on carbon emissions in China, *Energy Economics* 32, pp.186-193.

Zheng, Y., Qi, J., Chen, X., 2011. The effect of increasing exports on industrial energy intensity in

China, *Energy Policy*, 39, pp. 2688-2698.

Zhang, Z.X., 2010a. The US proposed carbon tariffs and China's responses, *Energy Policy* 38, pp.2168-2170.

Zhang, Z.X., 2010b. Copenhagen and beyond: reflections on China's stance and responses, East-West Center Working Papers, No. 111, available at http://papers.ssrn.com/sol3/papers.cfm?abstract_id=1586058

Zhang, Z.X., Baranzini, A., 2004. What do we know about carbon tax? An inquiry into their impacts on competitiveness and distribution of income, *Energy Policy*, 32, pp.507-518.

Zhao, X., Ma, C., Hong, D., 2010. Why did China's energy intensity increase during 1998-2006 : decomposition and policy analysis, *Energy Policy* 38, pp.1379-1388.

Zhou, N., Levine, M.D., Price, L., 2010. Overview of current energy-efficiency policies in China, *Energy Policy* 38, pp. 6439-6452.

Zhou, S. (Minister of the Environmental Protection of China), 2008. Preface, In: Zhang, K., Pan, J., Cui, D., (Eds), *Introduction to low carbon economy*, China Environmental Science Press, Beijing. (in Chinese)

Zhu, H., 2005. Meeting requests of scientific development by improving energy balance statistics, *Energy of China*, 2005 (07), pp.16-20. (in Chinese)

Zhu, S., 2001. Green house gases emissions and reduction in cement sector, *China Energy* 2001(07), pp.25-28. (In Chinese)

Zylbergerg, A., 2000. La théorie de l'équilibre général de 1918 à 1938, in Béraud, A, Faccarello, G., Eds, *Nouvelle Histoire de la Pensée Economique*, Tome III, La Découverte, Paris, pp. 162-191.