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Etudes et Documents

Ec 2003.15

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octobre 2003
44 p.

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[Ψ] I would like to thank David Roland-Holst of University of California, Berkeley, for his generous offer to me to share his China prototype CGE model and the related benchmark SAM, also for all his instructive and patient suggestions during the realisation of this research. Surely I am responsible for all the errors in the paper myself.

Estimation on Economic Cost of China's New De-sulfur Policy During Her Gradual Accession to WTO: The Case of Industrial SO2 Emission

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Abstract

To understand the potential impacts of China’s accession to WTO in her new de-sulphur policy (reduction of 10% of SO_2 emission in 2005 with respect to that of 2000), we construct a CGE model in which the SO_2 emission is linked directly to energy intermediary consumption in production. The positive externality of trade on China’s economy is also included. This model is then calibrated into a 55-sector Chinese SAM of year 1997. Four policy simulations (BaU, Open, Desulfur, Open+Desulfur) are made for 1997 till 2005 and the Divisia index decomposition method is used to analysis the simulation results. The principal results show the environmental impact of trade, though proven to be “negative”, stays rather modest. This is due to the effect of industrial composition transformation that deviates towards labor-intensive sector specialization under the new trade liberalization process. We also find supposed some modest trade externality effect to contribute to pollution reduction and we do not find proof for “pollution haven” hypothesis. Although seemingly to be quite ambitious, the new de-sulphur policy will only bring very slight economic growth lose. The most part of pollution reduction will be realized by the substitution between polluting and less or non-polluting energies. The combination of the trade liberalization and pollution control policies seems to give China more flexibility in adapting her economy to the new de-sulphurs objective. Considering different aspect together, the total economy loss due to new de-sulphur policy will be limited to only –0.18% under the presence of trade liberalization.

Keywords: CGE, Trade, Industrial SO_2 pollution, Energy substitution, Externality.
JEL classification: C68, F18, Q25, Q43,

1. Introduction

China's last ten years' economic growth was characterized by a high growth rate. According to China's official statistic data, the real average growth rate of GDP was over 8 percents during 1990-2000. The per capita GDP almost tripled in the last ten years, from 1634 Yuan of year 1990 to 3843 Yuan of year 2000. Like many East Asian countries, China's economy growth is also characterized by remarkable increases in the ratio of industrial activity integrated in whole economy, from 37% of year 1990 to 52% of year 1999.[1] This is not only reflected in fast increase in the ratio of international trade to GDP, but also by an enormous inflow of foreign direct investments.

Unfortunately, China's economy growth success is accompanied by rapid environmental deterioration as many of her southeast neighbors. Due to the concentration of industrial activities and population, since the 1980s, SO_2 pollution in China's urban regions has increased dramatically. In over one third of Chinese big cities, SO_2 concentration level is at least twice higher than the standard fixed by the WHO (World Health Organization) for the developing countries.[2] Some studies have already revealed the negative impact that SO_2 pollution have on people's health, especially as a significant cause for respiratory diseases in China.[3] Meanwhile, the serious acid rain problem aroused by SO_2 emission in some southern provinces has resulted in rapid equipment and soil productivity reduction.[4]

Given the various theoretical assumptions and the general incoherence among the corresponding empirical findings, trade-environment nexus still stays rather ambiguous. Moreover, since most of the empirical works based on data of international level, the traced (efficient or not) general experience among different countries seems unsuitable to be extrapolated to explain the possible environmental impacts of trade openness for a single country. Especially for China, her extremely rich coal resource, as the principal cause for her SO_2 air pollution problem is indicating at the same time possibly the most simple and efficient path to reduce pollution---reduce the emission of sulfur from coal combustion. While at the same time, her generally accepted successful SO_2 pollution abatement achievement seems also to be a quite particular story for the countries of the same income level. So, how could we explain China's environment evolution given her economy growth and trade openness trajectory? On one hand, "pollution haven" hypothesis assumes that given China's low income level, further openness process will lead China to be an attractive concentrating place for "world" factory of pollution industries, since her low income level does not permit her to attach as much importance on environmental quality as their rich trade partners. However, lots of theoretical and empirical analyses tried to show the infeasibility of this hypothesis. Copeland and Taylor (1994, 1997) and Antweiler et al (2001) showed "either positive or negative, the impacts of trade will be small to environment. They reasoned that besides the comparative advantage of a country coming from her environmental regulation strictness, the traditional comparative advantages decided by natural endowments of a country would also be a very important factor to influence the international division of production. Given China's comparative advantages are in labor-intensive sectors, and we generally believe that labor-intensive industries are normally less pollutant than capital-intensive ones, China's position in world production system in fact depends on the weighing of these two comparative advantages of opposite directions. Furthermore, from a more dynamic point of view, the deepening of openness process might in long run reinforce the production efficiency of China's domestic producer, both through the ever-increasing direct import of foreign

[1] China's Statistic Yearbook, (1990-2000).
[2] China's Environment Statisitic (1998).
[3] Xu et al,1994, Wells, Xu et Johnson, 1994 et World Bank, 1996a.
[4] World Bank, 1996b.

equipment that embody the advanced technologies, and through the positive externality of export that has been often used to explained the economy take-off of the four Asian dragons' economy.

Entering into the new century, China's economy and environment face unprecedented challenges and opportunities. On one hand, China's accession to WHO, assigned at the end of 2001, will lead China to enter a totally new era for her economy growth. According to the related articles in GATT (1994), from the beginning of year 2002, China begins to gradually implement her commitments related to the accession to WTO, a large reduction in tariffs, subventions and a gradual phasing out of the NTBs are envisaged in China for the following 15 years. This further deepening of open process will unavoidably accelerate China's economic structure transformation and environmental situation evolution. On the other hand, in June, 2001, China's State Environment Protection Agency (SEPA) called for a further cutting down of total SO_2 emission by 10% national wide and 20% in the two control zones (Acid-Rain Control Zone and SO_2 Emission control Zone) by year by basing on the SO_2 emission volume of year 2000.[5] Since these two policies are implemented almost during the same period (2001-2005), this undoubtedly offers us a perfect policy background to analyze the trade-environment nexus. Given the future SO_2 emission ceiling fixed by the new de-sulfur policy is based on the emission level in year 2000, to attain the new de-sulfur policy's objective, China should reduce on one hand the original SO_2 emission growth caused by a "Business as Usual" economy growth, and includes the further industrial SO_2 emission variations caused by China's commitments related to her accession to WTO. If China's SO_2 emission will, as anticipated by "pollution haven" hypothesis, increase with the deepening of her open process, the new de-sulfur objective will become more costly for Chinese economy in the future years. On the contrary, if the new de-sulfur policy seems cost less to economy growth under the on-coming openness process, we can conclude that trade plays in fact an environmental amelioration role.

Given the reasoning, to answer the question whether China's new SO_2 pollution control attempts will becomes easier or harder to accomplish side by side with her new opening process, in this paper, we apply the recent prototype of a Real China's Computable General Equilibrium Model of Roland-Holst and van der Mensbrugghe (2002), combined with the Trade and Environment EQUILibrium Analysis model (TEQUILA) developed by OECD development Center for its suitable Development research program to include the trade-environment nexus and the trade-externality computable general equilibrium model of De Melo and Robinson (1990) to enter the externality consideration. Using this model, we investigate the possible trade-environment nexus, by specially focusing on the possible environment and economy impacts parallel trade liberalization and SO_2 emission abatement policy. Different from the TEQUILA model, instead of using the estimated input-based effluents intensities (Dessus et al., 1994) obtained by matching data from a social accounting matrix disaggregated at the 4-difit ISIC level of United States to the corresponding database of IPPS pollution database of World Bank (Martin et al., 1991), we use the actual SO_2 emission and corresponding fuel energy (coal, oil and natural gas) input data in different industrial sectors in China from year 1991 to 1998 to estimate econometrically (penal data method) the direct energy input-SO_2 emission coefficient. Since the emission levy system is only applied on industrial and commercial emission, we further calculate the energy-specific SO_2 emission tax rate for these taxable sectors according to the estimated effluent coefficient according to the actual emission levy system implemented currently in China. Given different fuel energy has different effluent rate, the emission tax paid by each sector will depend on the quantity and composition of their intermediate fuel energy consumption. Since we suppose

[5] *Beijing Environment, Science and Technology update*, 14, June 2002. The base the emission level of year 2000. Further explication to two control zones can be found in the second section.

substitution possibility between different energy, for a producer, to reduce their emission tax, which means directly to reduce their SO_2 emission, he has two possible ways: reduce the total consumption of the energy input and reduce the ratio of the more pollutant fuel energies in his energy input bundle.

Following, we calibrated the model into the detailed SAM of 55 sectors in year 1997. Using the available statistic data on the growth rate of GDP, population and labor forces as the exogenous dynamic from 1997-2001 and then the assumed constant growth rate of these two economic variables between 2002-2005, we firstly make the Business as Usual (BaU) scenarios where Chinese economy will continue under current situation with an annual economy growth rate of 7.0%, population growth rate of 0.8%, and labor growth rate of 1%. We equally suppose the depreciation rate to be 0.05. Following, three recursive dynamic simulations are made to measure the potential economic cost of the new de-sulfur policy and to capture the possible variation of SO_2 pollution under China's open process. First is the scenario (OPEN), which includes the foreseen China's gradual tariff reduction promise during 2002-2005. Then, to measure the economic cost of the new de-sulfur policy, one simulation is carried out the new de-sulfur policy in China's current economic situation (DeSulfur). At last, in another simulation (DeSulfur+OPEN), the same de-sulfur policy is carried out side-by-side the supposed openness process.

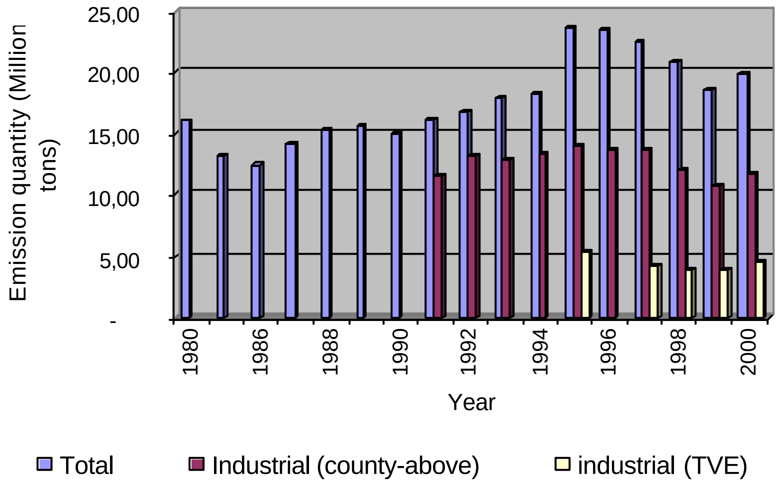
Comparing the different scenarios, we would like to get information on the possible difference in their economic growth rate, which is considered as the most important economic cost indicator for emission polices and the different channels that result in this results. Moreover, according to Grossman (1995), since emission is considered as a "by-product" of production that determined by the three famous characters of economy: scale, composition and technique effect and that trade can have effects on Chinese economy through all of these aspects. To seize the different channels through which trade exerts its influence on environment and we will employ further the Divisia index decomposition method (Yang, 2001) to measure the different contribution of the variation in these three aspects' characters of economy by these policy application in SO_2 emission evolution.

The organization of the paper is as following. After this introduction, we will provide a short introduction on the evolution of China's de-sulfur policies during the last ten years. Section 3 is contributed to model specification and the simulation procedures and corresponding results are presented in section 4 and 5. Finally, we conclude in section 6.

2. China's environment pollution situation and pollution control policy

Since 1985, China's SO_2 emission increased quickly with her economic growth, industrial production activities became the largest SO_2 pollution source. From Figure 1,we can see the industrial SO_2 pollution under the authority of county-level government experienced a very rapid climbing during the first half of 1990's. At the same time, the initially discovered acid rain problems in the 1980s in some southwest provinces has been enlarged to many southwest, central, south and northeast provinces due to the SO_2 emission increase. However, we equally observe a clear declining tendency in all three SO_2 emission indicators shown in the figure. The amelioration in SO_2 emission situation during 1996-1999 might owe to the ever-reinforcing pollution control efforts of SEPA in the last years.

Figure 1. Evolution of SO2 emission in China during economic reform period



Data Sources: China Energy Databook vs. 5.0 and China's Environment Statistics Yearbook

The current SO_2 pollution control system implemented in China is the so-called "Total Emission Quantity Control (TEQC)" system. Under this system, the polluters, principally industrial and commercial enterprises, are asked to pay for their pollution emission exceeding the relevant national or local pollution standard, and "the original pollution levy rules stipulated that 80% of the levy revenue is to be used to fund pollution prevention measures".[6] This system was firstly applied since 1993 in two provinces and nine cities. However, at the beginning, the implemented levy rates in this system were relatively too low (only 40 yuans/ton of SO2 emitted at average level).[7] Although Table 1 shows this levy system reinforced its policy strength by increasing levy rate and two other provinces, Hebei in 1995 and Shaanxi in 1996 also began to implement SO_2 Charges, this policy seems always not enough efficient to incite producers to exercise actual emission abatement activities, as the levy rate "in some cases being only 25% of the pollution control cost".[8] Many people have doubts on the efficiency of this levy system in pollution reduction. From economic point of view, facing very low levy charge, some polluter may prefer to pay levy charge instead of taking measures to abate their pollution emission. Therefore, a large part of pollution reduction in the last ten years that we observed from figure 1 should be owed to the pollution abatement initiatives funded by the over 80% of the revenue collected from pollution levy. Clearly, we can expect a further progress in pollution reduction by reinforcing efficiency of the levy system and strengthening polluters' abatement initiative.

[6] Cao et al (1999).
[7] Cao et al (1999).
[8] Wang (1996), Taxation and Environment in China : Practice and Perspectives, in OECD ed. *Environemental Tax : Recent Development in China and OECD Countries*.

Table 1. Evolution of China's SO_2 pollution levy system in 1990s

	Charge Rate (Yuan/ton)	Scope of Application[1]	Total Charge in 1997 (10^6 Yuan)	Year	SO_2 emission charge revenu (10^6 yuan)	Average SO_2 Charge in national level[2] (yuan/ton)
Guangdong Province	200	Coal and oil	58.52	1993	19.7	1.10
Guizhou province	200	Coal	15.97	1994	77.2	4.23
Chongqing city	5 yuan/ton coal	Coal	7.34	1995	122.6	5.17
Yibin City	180	Coal	7.36	1996	146.2	6.20
Nanning City	200	Coal	8.45	1997	179.2	7.36
Liuzhou city	200	Coal	na	1998	515.095	24.63
Guilin city	200	Coal	na	1999	861.3262	46.37
Yichang city	200	Coal	11.43	2000	776.031	38.90
Qingdao city	200	Coal	39.41			
Hangzhou city	180	Coal	9.19			
Changsha city	200	Coal	3.89			

Note: [1] Energies in industrial and commercial usage.
[2] Here, we use total SO_2 emission quantity to divide the total SO_2 charge revenue to get the national level average SO_2 emission levy rate. (Unit: Yuan per ton of SO_2)
Data source: Cao (1999) and China's Environment Statistic Yearbook.

At the beginning of 1998, SEPA went further in their de-sulfur program by defining the cities and provinces suffering most seriously SO_2 pollution and acid rain problems into two special zones (Acid-Rain Control Zone and SO_2 Pollution Control Zone), where we apply more stringent pollution control strategy. Since this two zones' SO_2 pollution amounts to two thirds of the total SO_2 pollution in national level, strengthening the pollution control in these two zones means in fact a significant progress in the total SO_2 control stringency in China, correspondingly, we see a triple of the average SO_2 emission levy rate in 1998 from Table 1.

Further reinforcement on environmental protection stringency is also expected in the period of 2001-2005. As mentioned in the introduction section, Chinese government plans to reduce total SO_2 emission by another 10% (20%'s reduction for the two zones) in the 2001-2005 period. If we take the newly established emission control standard (10% less with respect to 2000 real emission level) serious, reinforcement in efficiency of the current emission charge system is necessary. Under the traditional "total emission control" levy system, to reduce the total emission control for each industry by 10%, how much should we lift the levy rate? How much will the increased levy rate enlarge the part of emission abated by polluters themselves as a reasonable private profit-seeking activity? We will also try to answer this question by our analysis.

3. Model Specification

The computable general equilibrium model we used in this paper is in fact inspired and combined by three models: the Trade and Environment EQUILibrium Analysis model (TEQUILA) of Beghin et al (1996), the trade-externality included model of De Melo et Robinson (1990) and the finally the most important, the recent prototype of a Real China's Computable General Equilibrium Model of Roland-Holst and van der Mensbrugghe (2002). In this model, the energy input usage is distinguished from the other intermediary input to be substitutable between them and with other production factor as labor and capital by a 6-layer production nesting. Furthermore, the positive technological externality of trade is also captured to analyze the links between trade and environment in different aspects. In this model, China's economy is divided into 55 sectors: 14 agriculture sector, 29 industrial sectors, in which the energy industries are composed four different sectors: coal mining, oil and coke, natural gas and electricity, one construction sector and 11 service sectors, in which include three transportation sectors: land, sea and air transportation. This model is calibrated into the most recent China's 1997 SAM.[9] The model is composed of production, income distribution and consumption, other final consumption, government revenues and saving, trade, domestic supply and demand, market equilibrium, and macro close rules and dynamics sections. The following paragraphs give a simple description of our model and the complete model is provided in the Appendix 1.

3.1 Production and emission arrangement

The production technology is specified that each economic sectors combined capital, labor, natural resource, land, electricity, fossil fuel and other normal intermediate input; using a 6-layered nested constant elasticity of substitution (CES)-Leontief production function designed to production of a specific product. The production nesting is shown in Appendix 2. This specification by distinguishing energy input from other intermediate input, and a further distinguishing of electricity to other fossil fuel is inspired by Beghin et al.(1996) and Yang (2001). According to general consideration, China's SO_2 emission is principally due to the heavy dependence of her production activity on fossil fuel combustion, especially coal, whose deposits in several provinces have an extremely high sulfur tenor. We suppose only production activities emit SO_2 pollution. By distinguishing energy input firstly from the other input, then a further distinguishing fossil fuel (coal, oil and gas) from electricity by attributing between the former a higher substitution elasticity (0.9) than that between electricity and fossil fuel (0.7), this energy-distinguishing arrangement will enable us to be free from a fixed ratio of energy use in each unit of product and realize an easier substitution between fuel and non-fuel energy inputs and between the energy bundle and capital and labor factors. Another consideration to use this arrangement comes from the actual operation of China's SO_2 pollution levy system. As shown in section 2, the so-called SO_2 levy system is in fact exercised by applying a tax on coal or oil use in industrial and commercial activities. Given the price-structure influence of this actual energy tax aiming at reducing SO_2 pollution, the attribution of substitutability between different energy inputs and that between energy and other production factors will enable us to extrapolate the possible conduction mechanism from energy related emission variation to energy composition changes in production and finally to SO_2 reduction results.

The conversion from energy input usage in production activities to SO_2 pollution follows the estimated effluent rate of different energy input in industrial sectors. Instead of extrapolating the input effluent rate regressed from the input-output data in U.S. social accounting matrix into the analyzed country by price and exchange rate adjustments as TEQUILA model. In this paper, we use real Chinese industry SO_2 emission and energy consumption data from 18 industrial sectors, which represent over 98% of the total industrial production during 1991-1998, to estimate econometrically the actual SO_2 effluent rate of coal, oil, and natural gas by employing panel data estimator techniques. The estimation results are shown in table 2. Obviously, the results are reasonable, with the most significant relationship between coal combustion and SO_2 emission and some less important but relatively significant link between oil consumption and SO_2 emission. While the insignificantly negative coefficients of gas input shows the fact that gas combustion arise almost no SO_2 emission. Since the Hausman test suggest a superiority of random effect result, we will use RE results to continue our analysis.

[9] Source : Roland-Holst and van der Mensbrugghe (2002).

Table 2. Estimated energy emission rate

Dependant variables: Industrial SO_2 emission (ton), panel data estimator (1991-1998, 18 sectors)

Explicative Var.[1]	**Random Effect (RE)**		**Fixed Effect (FE)**	
	Coefficient	**T-value**	**Coefficient**	**T-value**
Coal consumption	0.0181581	5.17***	0.0184979	5.12***
Oil consumption	0.0099582	1.40*	0.011331	1.51*
Gas consumption	-0.0083825	-0.88	-0.0098472	-0.99
Year	-5830.464	-0.63	-6596.19	-0.70
Constant	1.20×10^7	0.64	1.35×10^7	0.72
Breusch-Pagan test	479.02 (0.000)			
Hausman test	0.47 (0.9763)			
R^2 adjusted	0.2254		0.2254	
Num. of Group	18			
Num. of obs.	144			

Note: [1] the energy usage is in physical unit, that is to say, TCE (tons of coal equivalence).

As the energies are accounted in universal physical unit – MTCE (million tons of coal equivalence), to transform this emission rate into per monetary unit of energy input indicated in 1997 SAM, we use the corresponding value of total industrial intermediate consumption of different energy inputs in 1997 SAM to divide the total energy input usage in physical unit to get a transformation shifter. To explain this procedure in mathematical way we have the following equation (1).

$$\underbrace{\frac{SO_2 emission}{energy(moentary)}}_{\text{Emission rate for each monetary unit of energy}} = \underbrace{\frac{SO_2 emission}{energy(physical)}}_{\text{Emission rate for each physical unit of energy}} \times \underbrace{\frac{energy(physical)}{energy(monetary)}}_{\textbf{Tranformation shifter}} \qquad (1)$$

By using total industrial energy consumption data in physical unit MTCE recorded in Chinese energy databook vs. 5.0 and the corresponding value data in 1997 SAM which in 1997 million USD (transformed from CNY by PPP exchange rate I USD=4.078 CNY), we obtain the transformation shifter between physical and monetary unit energy's emission rate and finally the SO_2 emission rate for each monetary unit of energy input. The results are given in Table 3.

Table 3. Transformation shifters and emission rate per monetary unit of energy inputs

	Transformation shifter (Inverse of energy price, CET ton/million USD)	SO_2 emission rate per million USD's energy (ton/Million USD)
Coal	35925.483 (27.84 USD/Ton CE)	652.339
Oil	3858.622 (259.16 USD/ Ton CE)	39.421
Gas	19417.549 (51.50 USD/ Ton CE)	0

Note: Physical unit intermediary energy consumption data in total industry come from China's Energy Databook Vs. 5.0, LBL) and monetary unit intermediary energy use data are from 1997 SAM (Roland-Holst and van der Mensbrugghe, 2002).

Therefore, we can derive the SO_2 emission calculation formula by using the found emission rate per monetary unit's energy as equation (2).

$$SO_2 = 652.339 \times Coal + 39.421 \times Oil + 0 \times gas + 0 \times Electricity \qquad (2)$$

3.2 Domestic Final demand section

Due to data constraint, this model has only one household group. Household's expenditure is characterized by a four-layer structure. At the first level, household transfers to foreign country a constant share. In the second level, household will save a constant share of their disposable income (after income tax) and on the third level, household consumption of goods and services is decided by a Linear Expenditure System (LES). This system includes a subsistence minimum, which increases with exogenous population growth and the part of consumption determined by the exogenously given income elasticity with respect to his discretionary income.[10] Finally, household consumption for each good is further decomposed into domestic and imported shares, which is actually resolved at national level by a CES function specification.

Other domestic demand includes government final consumption, investment consumption and volume of services exported in international trade and transport activities. Different from the arrangement in household consumption, consumption of each good for each final demand is determined by a constant ratio with respect to the total aggregated quantity of consumption, which is in turn determined exogenously (excepts investment consumption) in the model.

3.3 Entreprise account

Enterprise's income comes from the distribution of profit of capital by a fixed share that calibrated from the information offered by SAM. Following, this income will be in turn distributed into enterprise saving, household profit share and foreigner profit share. The ratios of the three shares are also exogenous and calibrated from SAM.

3.4 Government account

The government revenue comes from following tax collection: production tax, intermediate consumption tax, income tax, consumption tax, valued added tax, import tariff, export tax (or subsidies), emission tax and all kind of transfer from foreign countries. Its expenditure is composed by government consumption, transfers to household, enterprises, and to the rest of world. The rest part of revenue after deducting expenditure constitutes government's saving, whose real value (with respect to the general price index of economy) is supposed exogenous.

In the model we consider all the tax rates as policy instruments and can be exogenously determined. Their original values are calibrated from SAM. The treatment of tax revenue from emission tax is a little special since this part of tax does not indicate separately in the original SAM. To included this de-sulfur policy instruments into model specification and SAM, we divide the total SO_2 emission charges revenue in 1997 (see Table 1) by the total SO_2 pollution in all the *industrial and service* sectors obtained from equation (2) to obtain so-called "national-wide average SO_2 emission tax rate", which is found to be 22.22 Yuan per ton of SO_2 emission.[11] Following, we further transform this average SO_2 emission rate into the energy-specific SO_2 emission tax rate by multiplying it with different energy effluent rate. This new energy-specific SO_2 emission tax rate will then help us to separate one part of

[10] Data sources: Roland-Holst and van der Mensbrughhe (2002).

[11] Note that the calculated "national-wide average SO_2 emission tax rate" is larger than the Average SO_2 Charge in national level shown in Table 1. This is due to the fact that the latter is calculated directly from the available statistical SO_2 emission data of the total economy, while the former is calculated from the estimated SO_2 emission converted directly from the intermediary energy consumption in industrial and commercial service activity recorded in the social accounting matrix, which should be smaller in its scale than the actual economy.

production tax revenue from each industry and service sector to constitute the levy charges revenue collection in government's account. We give out in table 4, without a more detailed procedure presentation, the energy-specific SO_2 emission tax rate for coal and oil input. Obviously, the emission tax rate is very low, the ad valorem wedges to the original energy price from this emission tax made only very slight price correction effect with respect to the SO_2 emission performance of these energies. For example, the ad valorem wedge for coal due to this very slight emission tax is only 0.3% and that for oil is only 0.021%. Given this low emission tax and its tiny energy price correction effect, we cannot expect significant reduction in energy consumption in producer's profit-maximization decision. Another statement here is that although SO_2 emission calculated in equation (2) includes all the energy usage in *production* activities, the emission tax will only be applied in *industry and service* sectors.

Table 4. Derived Energy-Specific SO_2 emission tax rate

Energy	Emission tax rate for energy per 1 Ton CE
Coal	(22.22 /4.07691)×0.0181581 =0.09865 US$
Oil	(22.22 /4.07691)×0.0099582=0.0543 US$

Note: Here we use the PPP exchange rate of CNY with respect to USD in 1997 which is 1 USD=4.07691 CNY.[12]

However, this arrangement to include emission tax into the model and SAM is only a very simple modification from a traditional CEG model. It only allows us to take the effect of emission taxation on pollution into consideration. Although Chinese pollution reduction exercise shows that 80-90% of the emission levy revenue has been used to funding pollution abatement activities, due to data limitation, currently we are not be able distinguish in more details the pollution abatement activities from the normal economic activities in our modeling and SAM presentation. However, since one of the questions that we are interested in this paper is how much higher the emission tax rate should be if we need to realize a active pollution abatement activity from producer side to attain the de-sulfur objective. We will currently satisfy with the simple consideration of the effect of emission tax increase on pollution abatement through input and goods price-structure modification decided by producer's "profit-maximization" principle. Surely, the possible changes in government and private pollution abatement investment caused by emission tax increase should also be a very important analysis subject of this analysis when more detailed data are available.

3.5 Trade section

Model assumes imperfect substitution between the goods from different origins and destinations in trade and between imports and domestic goods and between domestic supply and export. We use the Armington constant elasticity of substitution function form to determine the composition of domestically produced good and aggregated imported goods. Then the aggregated imported goods are further allocated into different origins by a second-level Armington CES demand function. On supply side, domestic production is allocated across different markets by a nested constant elasticity of transformation (CET) specification. Here, we also assume an imperfect transformation between different markets from the point of view of producers. Firstly, producer use this CET specification to decide the allocation of product into domestic and foreign market, and at the second level, the orientation of the exported products will be further decided by another CET function according to the different producer's price which comes from the world price deducted the export taxes. We follow small country hypothesis, the world prices for export and import are supposed to be exogenous. The trade distortions shown in different export and import prices of different

[12] Roland-Holst and van der Mensbrugghe (2002).

origins and markets are caused by the different ad valorem tariffs and export taxes (or subsidies) imposed by government, which are also, exogenous to the model.

3.6 Market equilibrium conditions and macro closure

We assume the domestic product demand to be equal to domestic product supply, where the equilibrium product price will be determined. For the import demand, the small country hypothesis permits automatic satisfaction of import demand without incurring variations in world price, so the one-price rule holds here. The same consideration is used for export, which will be totally absorbed by foreign market without exerting price variations in world market.

In macro closure, we suppose government fiscal balance is endogenous. Investment is driven endogenously in the model by the sum of different saving coming from household, enterprise, government and rest of world. Trade balance is equally supposed to be endogenous, and the same for balance of payment, since we suppose fixed exchange rate system for RMB in our model.[13]

3.7 Factor market equilibrium

All the four factor markets, labor, capital, land and other natural resource are supposed to be cleared up. Since the data does not permit us to distinguish between the labor of different skill level, we assume labor to be perfectly mobile between sectors. The labor market equilibrium will determined the unique equilibrium wage, while the exogenous salary difference between sectors is calibrated from the original data. We suppose the imperfection substitution for capital between sectors, by employing a CET specification, we allocate capital into different sectors according to their capital rents' differences. Land supply is supposed to be a fixed aggregate quantity; the land allocation between different sectors follows the same CET arrangement for capital factor. While the natural resources in this paper design some very specific resources needed uniquely in some special sectors, such as the mine for coal mining sectors, etc. In the model, we suppose zero-mobility for these resources and their demand floats according to their price with respect to the general price index that evolves with the time.

3.8 Positive Externality from international trade to economy growth and structural transformation

Till now our model includes the effect of tariff and subsidies variation to affect prices of products and inputs through the CET and CES functions that describe the producer and household's decision. Facing to these price changes, a profit-maximizing producer will change his production and input consumption decision and a utility-maximizing consumer modifies his consumption composition between imported and domestic goods. Like this, both the demand and supply, also the economy structure, employment, exports, import, investment, and even the abatement activities will all be chained to change.

While observing the important growth-led effect of international trade in China's economic history in the last 20 years and the general experiences from the South Asian four dragons. We expect something more from this deepening of openness process for Chinese economy than the simple economic structure changes, which is called as "export-led" economy growth. De Melo and Robinson (1990) on the case of South Korea, and then Rodrigo and Thorbecke (1997) on the case of Indonesia has managed to capture the possible

[13] This arrangement might be changed in the future development of this model.

positive externality of trade (both through export and import) into economy growth into their CGE model specification. To seize some possible externality from trade in Chinese economy, we also add the trade-externality specification in the model.

The principal hypothesis for the trade-externality in this model is the following.

Firstly, industrial sector's export increase can reinforce productivity of all the production factors used in this sector by a universal level. To export means to meet more intense competition in world market, and an increase in export volume reflects an augmentation of competitiveness of domestic producers. Since domestic market is perfectly competitive, higher export volume reflects in certain degree a strengthening in the productivity on the whole industry-level. At the same time, given to be an externality, this augmentation of productivity owing to export growth cannot be pursued by the decision of a single producer to export more to the world. To express this idea in the model, we follow the model specification of Rodrigo and Thorbecke (1997) to make the following modification to our model.

The production function reflects the externality from export is

$$KLE_j = AT_j \left[a_k(?_k \times K_j)^{?} + a_{ene}(?_{ene} \times ENE_j)^{?} + a_l(?_l \times L_j)^{?} \right]^{1/?} \quad (3).$$

Where AT_j represents export externality. Upon the traditional CES production system, where, as usual, a_x is the share parameter, r is CES exponent related to elasticity of substitution between the production factors, we add the term $AT_j = \overline{AT}_j(\frac{\overline{E_k}}{E_{0k}})^{f}$ and $\overline{AT} = 1$. This is the productivity shifter due to the increase in export volume, where the E means export volume and the index 0 means its original period's value. Following the experience of De Melo and Robinson (1990), we choose here a fairly small value of 0.1 for externality parameter j to describe the export externality for China's case since her export may means less growth-led effect than that of South Korea of twenty years ago. By this modification, we expect to capture more positive economic influence of export under China's gradual opening process during 2001-2005.

Following is the positive externality coming from accumulation of imported machinery and equipment. China's new open policy will facilitate the import of foreign equipment embodied advanced technologies. Given the close link between upstream and down stream sectors and the productivity growth coming from the effect of learning by "doing" and even learning by "watching", the positive technique progress effect of the imported machinery can, very possibly spill over the frontier of the enterprise to reach even all the economy. To capture this external effect, we modify further the production function as equation (4) where we suppose the increase in imported machinery and equipment import will cause an actual increase in effective capital in the economy.

$$KLE_j = AT_j \left[a_k(?_k \times BT \times K_j)^{?} + a_{ene}(?_{ene} \times ENE_j)^{?} + a_l(?_l \times L_j)^{?} \right]^{/ ?} \quad (4)$$

Where BT represents externality sourcing from import of advanced machinery, which increase capital's productivity in all the sectors. And mathematically, this import-externality shifter is as following.

$$BT = \overline{BT}\left(1 + \frac{?_{hp} M_{hp,t}}{?_{hp} ?_{T=0}^{t} M_{hp,T}}\right)^{?} \quad (5)$$

Here M means the imported machinery and equipment, index t means period t, and $\overline{BT}=1$. This equation indicates that the importance of the import-externality depends on the increase of the total stock of imported equipment and machinery that accumulates since the very beginning. A more concrete explication for this externality is that, the increase in the stock of the imported machinery will lead the volume of effective capital supply for the economy as a whole to increase. For the sector j in equation (4), the effective capital used in production is $BT \times K_j$. Here the externality parameter ψ is supposed to be 0.1 as Rodrigo and Thorbecke (1997).

With this new production function which is characterized the external technological aspects, the producer's solution for their objective of maximization of profit will get some modification, for the detailed results, please look into the model specification at the end of the paper.

4. Policy scenarios

After calibrating the model into the most recent social accounting matrix of China in 1997, we employ the available statistic data on growth rate of GDP during 1997-2001 and the forecast constant economy growth rate between 2002-2005 (more details can be found in table 5) to make the first simulation. This simulation aims to find the corresponding endogenous productivity growth rate for different production factors such that the forecasted GDP growth trajectory can be realized. Here, as we attribute to energy input some characters similar to the traditional production factors; we suppose energy input enjoy the same productivity growth rate as capital and labor. All policies instruments are held exogenous and constant in simulation, except SO_2 emission tax rate that is permitted to evolve between 1997 -2000 to capture the already achieved pollution reduction results during these years. The evolution of population and labor forces growth are also held exogenous according to their given value during 1997 and 2000 then supposed to have a constant growth rate during the later 5 years.

Table 5. The related exogenous variable evolution in simulations

Exogenous variables	Year	Annual growth rate	Exogenous variables	Year	Annual growth rate
GDP (percent)	1997	8.8	Labor Force	1997	10.89
	1998	7.8	(Percent)	1998	14.79
	1999	7.1		1999	10.72
	2000	8.0		2000	9.68
	2001	7.3		2001	13.04
	2002-05	7.0		2002-05	10.00
Population (1/1000)	1997	10.06	Capital Depreciation	1997	0.05
	1998	9.14	rate (Percent)	1998	0.05
	1999	8.18		1999	0.05
	2000	7.58		2000	0.05
	2001	6.95		2001	0.05
	2002-05	7.00		2002-05	0.05

Following, To measure the potential economic cost of the new de-sulfur policy and to capture the possible variation of SO_2 pollution under China's open process, four recursive dynamic simulations are made. This time, the found factor productivity growth rate from the first simulation is included exogenously. The first policy scenario is the Business as Usual (BaU) scenarios in which all policy instruments stay constant as there are neither the new de-sulfur policies nor the tariff reductions commitment. In this scenario, we only use the calibrated factor productivity growth rate to re-find the supposed economy growth trajectory that we supposed for this BaU scenario. Then, to measure the economic cost of the new de-sulfur policy, we implement the DeSulfur scenarios. In this simulation, the actual 10% SO_2

emission reduction objective is supposed to be achieved gradually during 2001 to 2005 (about 2% each year) by a corresponding gradual endogenous increase of SO_2 emission tax during these 5 years. The OPEN scenario measures possible economy and SO_2 emission changes caused by China's gradual process to access to WTO. According to the contents of Uruguay Round of Multilateral negotiation, after accessing to WTO, China should gradually reduce her tariff level by 30-36% in different sectors and eliminate gradually her export taxes except some specific merchandises according to the agreement with WTO. The tariff reduction schedule during 2001 to 2005 for the 55 sectors that we will apply in the simulation is given in table 6. Due to data constraint, we suppose a uniform reduction of export tax in all the sectors by 50% each year with respect to precedent year 2002 till 2005, which means a total reduction of export tax about 93.75% during the five years. To impose a sizeable trade shock on China's economy to estimate the possible changes in industrial composition and trade distribution between different sectors, we further assume some exogenous improvement of terms of trade for China's export owing to her integration, which is expressed as increases in world export price of 2% each year during 2002 to 2005. The last policy scenario DeSulfur+OPEN is to combine the two policy reforms to investigate the possible role of trade in China's SO_2 emission evolution. If trade is an environment-friendly factor in China's economy, with the further open policy, China's industrial composition will deviate to less polluting sectors, more precisely, the labor-intensive light industries. Trade-externality will also help domestic producer to increase their factor productivity in production and reduce their dependence in use of heavily polluting energies. In this case, the SO_2 emission reduction policy will cost less heavily on economy growth. While if trade is proven to be environmentally unfavorable factor, we will observe increase of the ratio of the heavily polluting sectors, since China's low income determines its "pollution haven" role for dirty industries. If this is the case, the 10% SO_2 emission reduction objective will weight heavier for Chinese economy.

5. Results

Before going into the detailed results of the four policy scenario simulations, we first check the evolution of China's economy and SO_2 pollution during 1997 till 2000. As shown in Table 7, Real GDP, gross output, absorption and real disposable income all grew by about 25% between 1997 and 2000. Investment growth went faster (33.21%), so did the industrial gross output (29.45%) and export (28.61%), and especially industrial export achievement (30.28%). While at the same time, due to the reinforcement of SO_2 pollution control revealed by a over 4 time's increase of emission tax, the economy growth seems to have been achieved by less pollution cost. SO_2 emission during the same period grew much slower (10.45%, in which 9.23% for industrial emission). An explication for this de-sulfur result should be explained by the parallel slower energy consumption growth, especially for coal (only 4.64%) and electricity (13.26%).

Detailed information on economic, pollution and energy consumption structure are displayed in table 8-10. As a typical industrializing country, China's over 58% of her production output comes from industrial sectors. Within industrial sector, excepts the traditional light industries as textile, wearing apparel and leather products keep their significant share in total industrial production, some newly emerging industries as chemical products, electronic equipment and other machinery and equipment sectors show also important increase of their share in gross output. Due to fast economy growth, construction industry occupies a quite high ratio in economy, and its upstream industry—other mineral products equally benefited from the increase in derived demand of construction and revealed a quite important ratio in industry sector.

Table 6. The tariff reduction schedule in China expected[1] (percents change from 2000)

Sectors	2000	2001	2002	2003	2004	2005
Paddy rice	100	80.94	46.96	46.96	32.32	32.322
Wheat	100	93.75	93.75	93.75	93.75	693.75
Cereal grains, n.e.s.	100	98.31	96.61	94.92	93.22	93.22
Vegetables and fruits	100	11.11	11.11	11.11	11.11	177.78
Oil seeds	100	88.98	77.97	66.95	55.93	55.93
Sugar cane and sugar beet	100	11.11	11.11	11.11	11.11	177.78
Plant-based fibers	100	11.11	11.11	11.11	11.11	177.78
Crops, n.e.s.	100	89.04	78.08	68.49	58.22	58.22
Bovine cattle, sheep and goats,	100	97.22	94.44	93.06	90.28	90.28
Animal products n.e.s.	100	97.22	94.44	93.06	90.28	90.28
Raw milk	100	90.99	81.98	72.97	63.96	63.96
Wool, silk-worm cocoons	100	90.99	81.98	72.97	63.96	63.96
Forestry	100	68.00	64.00	60.00	60.00	60.00
Fishing	100	68.00	64.00	60.00	60.00	60.00
Coal	100	90.48	85.71	83.33	83.33	80.95
Oil	100	76.32	76.32	76.32	76.32	76.32
Gas	100	76.32	76.32	76.32	76.32	76.32
Electricity	100	76.32	76.32	76.32	76.32	76.32
Other minerals	100	90.48	85.71	83.33	83.33	80.95
Bovine, sheep and horse meat products	100	90.29	80.58	70.87	61.65	55.83
Other meat products	100	90.29	80.58	70.87	61.65	55.83
Vegetable oils and fats	100	90.29	80.58	70.87	61.65	55.83
Dairy products	100	90.29	80.58	70.87	61.65	55.83
Processed rice	100	90.29	80.58	70.87	61.65	55.83
Sugar	100	90.29	80.58	70.87	61.65	55.83
Other food products	100	90.29	80.58	70.87	61.65	55.83
Beverage and tobacco	100	84.82	69.65	54.47	39.30	38.13
Textiles	100	88.89	66.67	55.56	44.44	33.33
Wearing Apparel	100	83.33	83.33	66.67	50.00	50.00
Leather products	100	100.00	100.00	100.00	50.00	50.00
Wood products	100	80.43	63.04	50.00	39.13	36.96
Paper products and publishing	100	80.43	63.04	50.00	39.13	36.96
Chemical, rubber and plastic products	100	93.75	87.50	81.25	75.00	68.75
Other mineral products	100	86.49	72.97	67.57	62.16	59.46
Ferrous metals	100	86.49	72.97	67.57	62.16	59.46
Other metals	100	86.49	72.97	67.57	62.16	59.46
Metal products	100	86.49	72.97	67.57	62.16	59.46
Motor vehicles and parts	100	84.00	68.00	58.00	48.80	41.20
Other transport equipment	100	76.19	76.19	73.81	71.43	71.43
Electronic equipment	100	66.67	33.33	24.24	24.24	24.24
Other machinery and equipment	100	80.00	62.50	55.00	52.50	52.50
Other Manufactures	100	93.75	87.50	81.25	75.00	68.75
Water	100	93.75	87.50	81.25	75.00	68.75
services and construction(11 sectors)	100	90.00	80.00	65.07	50.00	50.00

Note: [1] Data source: Wang (2002).

Table 7. Macroeconomic changes

Items	Real value							Comapraison (percent change from reference)				
	Unit	1997	2000	BaU	Desulfur	Lib	Desulfur+Lib	2000 (vs. 1997)	BAU (vs. 2000)	vs. BAU Desulfur	Lib	Desulfur+lib
Real GDP	10^9 US$	854,69	1073,61	1524,14	1509,92	1536,44	1521,35	25,61	41,96	-0,93	0,81	-0,18
Aggregate output	10^9 US$	2280,77	2858,15	3946,33	3911,84	3970,29	3934,55	25,32	38,07	-0,87	0,61	-0,30
Industry	10^9 US$	1337,69	1728,85	2516,32	2481,81	2542,65	2506,47	29,24	45,55	-1,37	1,05	-0,39
Private consumption	10^9 US$	414,09	519,47	696,57	693,63	711,70	708,55	25,45	34,09	-0,42	2,17	1,72
Investment	10^9 US$	310,00	412,95	628,83	625,01	642,49	638,59	33,21	52,28	-0,61	2,17	1,55
Export	10^9 US$	235,93	303,43	467,36	460,30	526,71	519,32	28,61	54,03	-1,51	12,70	11,12
Industry	10^9 US$	209,51	272,59	417,06	410,30	475,68	468,65	30,11	53,00	-1,62	14,06	12,37
Import	10^9 US$	245,26	319,53	503,84	500,17	594,50	590,61	30,28	57,68	-0,73	18,00	17,22
Industry	10^9 US$	214,69	273,41	409,32	408,53	505,27	504,36	27,35	49,71	-0,19	23,44	23,22
Absorption	10^9 US$	828,44	1036,77	1429,75	1422,99	1458,54	1451,49	25,15	37,90	-0,47	2,01	1,52
Real disposable income	10^9 US$	750,34	937,79	1250,31	1245,37	1276,93	1271,59	24,98	33,32	-0,39	2,13	1,70
Per capita	US$	606,95	738,30	949,93	946,18	970,17	966,11	21,64	28,66	-0,39	2,13	1,70
Total SO2 emission	10^6 tons	8,260	9,123	10,959	8,204	11,078	8,204	10,45	20,12	-25,13	1,09	-25,13
Industrial	10^6 tons	7,359	8,039	9,514	6,916	9,615	6,906	9,23	18,35	-27,30	1,06	-27,41
Total coal input	10^9 US$	9,28	9,71	10,66	6,80	10,74	6,75	4,64	9,77	-36,14	0,82	-36,69
Industry	10^9 US$	8,79	9,16	10,04	6,35	10,13	6,29	4,29	9,56	-36,79	0,84	-37,33
Total oil input	10^9 US$	56,01	70,78	101,65	95,52	103,24	96,49	26,37	43,62	-6,04	1,56	-5,08
Industry	10^9 US$	41,28	52,27	75,20	70,43	76,36	71,07	26,64	43,87	-6,35	1,54	-5,50
Total gas input	10^9 US$	1,11	1,29	1,60	1,74	1,62	1,76	15,95	24,57	8,57	0,81	9,72
Industry	10^9 US$	1,08	1,25	1,56	1,70	1,57	1,72	15,94	24,58	8,77	0,78	9,89
Total electricity input	10^9 US$	31,10	35,22	43,02	46,22	44,13	47,56	13,26	22,14	7,44	2,57	10,55
Industry	10^9 US$	26,21	29,55	36,09	39,15	36,97	40,25	12,74	22,13	8,48	2,46	11,53
Emission tax (1997)	US$ / Kg	0,00545	0,00545	0,00545	0,00545	0,00545	0,00545					
Emission tax (2000)	US$ / Kg		0,0288	0,0288	0,0288	0,0288	0,0288	428,54	0,00	0,00	0,00	0,00
Emission tax (2001)	US$ / Kg			0,0288	0.30	0,0288	0.30		0,00	1041.67	0,00	1041.67
Emission tax (2002)	US$ / Kg			0,0288	0,63	0,0288	0.65		0,00	2187.50	0,00	2256.94
Emission tax (2003)	US$ / Kg			0,0288	1.02	0,0288	1.08		0,00	3541.67	0,00	3750.00
Emission tax (2004)	US$ / Kg			0,0288	1.48	0,0288	1.61		0,00	5138.89	0,00	5590.28
Emission tax (2005)	US$ / Kg			0,0288	2,05	0,0288	2,23		0,00	6998,95	0,00	7625,35

Table 8. Structure of production in 1997 and the variation in 2000

Sector	Share in Gross output (%)		Export/output (%)		Import/domestic sales (%)	
	1997	2000	1997	2000	1997	2000
Agriculture	**11,53**	**12,05**	**2,34**	**1,13**	**3,18**	**6,18**
Paddy rice	1,00	1,22	0,43	0,11	0,01	0,03
Wheat	0,49	0,45	0,16	0,08	6,56	11,99
Other cereal grains	0,56	0,50	7,26	4,13	5,80	10,06
Vegetables and fruits	3,50	3,68	1,61	0,63	0,94	2,42
Oil seeds	0,36	0,31	3,56	2,14	19,02	28,51
Sugar cane and beet	0,04	0,04	0,09	0,04	0,06	0,15
Plant-based fibers	0,31	0,31	0,06	0,03	16,84	27,32
Other crops	0,16	0,12	34,93	24,07	16,72	25,36
Bovine cattle	0,24	0,31	0,96	0,22	0,13	0,57
Other animal products	3,08	3,19	2,05	0,85	1,20	2,88
Raw milk	0,07	0,11	0,28	0,05	0,24	1,35
Wool, silk-worm cocoos	0,16	0,17	1,55	0,55	11,48	27,42
Forestry	0,54	0,60	1,09	0,50	7,32	14,84
Fishing	1,01	1,03	2,61	1,40	0,53	0,99
Manufacturing	**58,65**	**58,49**	**15,66**	**15,77**	**15,99**	**15,80**
Coal	0,50	0,42	10,95	9,90	0,89	0,99
Oil	2,46	2,46	6,69	9,20	16,39	12,19
Gas	0,07	0,06	17,05	19,15	0,00	0,00
Electricity	1,54	1,22	0,61	1,25	0,02	0,01
Mining	1,41	1,48	2,15	1,88	7,92	9,00
Bovine cattle, sheep	0,10	0,08	3,15	2,61	13,34	15,78
Other meat products	0,55	0,51	9,67	5,08	8,66	16,00
Vegetable oils and fats	0,48	0,44	4,91	4,13	30,63	34,66
Dairy products	0,05	0,04	4,17	4,85	21,79	19,21
Processed rice	1,65	1,54	0,82	0,59	0,83	1,15
Sugar	0,03	0,02	21,75	15,74	39,44	49,37
Other food products	1,57	1,42	12,16	9,71	8,02	10,08
Beverages and tobacco	1,78	1,81	2,62	2,16	4,16	5,02
Textiles	5,00	4,95	17,47	17,68	20,11	19,89
Wearing apparel	2,17	2,12	48,61	47,45	9,31	9,71
Leather products	1,69	1,36	54,94	49,36	14,99	18,04
Wood	0,96	0,97	19,13	17,51	8,70	9,60
Paper prod., publishing	1,75	1,72	4,14	4,03	16,57	16,96
Chem. Prod., rub. plast.	6,78	6,81	10,57	11,94	20,26	18,13
Other mineral products	4,58	4,69	5,01	5,02	3,78	3,77
Ferrous metals	3,16	3,24	5,97	6,14	13,28	12,95
Other metal	1,27	1,33	8,12	8,50	19,39	18,62
Metal products	2,43	2,48	12,47	12,56	6,55	6,50
Motor vehicles	1,50	1,51	3,84	4,26	12,88	11,71
Other trans. equipment	1,15	1,19	12,81	12,81	17,66	17,66
Electronic equipment	3,07	3,26	44,79	45,13	45,32	44,97
Other mach. and equip.	8,27	8,52	16,45	16,79	23,22	22,79
Other manufactures	2,51	2,68	39,08	40,64	7,51	7,07
Water	0,18	0,17	0,23	0,33	0,66	0,45
Construction	**9,22**	**9,83**	**0,26**	**0,22**	**0,72**	**0,84**
Services	**20,60**	**19,72**	**4,20**	**4,68**	**4,38**	**4,40**
Trade	6,50	6,54	5,00	4,53	4,89	5,39
Land transport	2,10	2,08	7,88	8,68	7,68	6,97
Sea transport	0,27	0,28	35,08	39,99	16,61	13,89
Air transport	0,34	0,36	38,07	44,82	30,03	24,48
Communication	0,98	0,88	1,86	3,53	2,03	1,06
Financial services	1,52	1,52	0,31	0,33	1,66	1,55
Insurance	0,23	0,22	8,19	9,15	18,34	16,59
Business services	1,21	1,14	4,62	5,03	6,71	6,18
Recreation and other services	1,30	1,29	0,52	0,48	4,47	4,83
Public services	5,40	4,58	0,89	0,78	1,21	1,38
Dwellinbgs	0,76	0,81	0,00	0,00	0,00	0,00
Total	**100,00**	**100,00**	**10,34**	**10,62**	**10,71**	**11,11**

Table 9. Structure of Pollution emission in 1997 and 2000

Sector	Share of SO2 Emission (%)			SO_2 intensity (ton/millon USD)		
	1997	2000	Variation	1997	2000	Variation
Agriculture	**2,40**	**2,67**	**0,28**	**0,75**	**0,86**	**0,11**
Paddy rice	0,08	0,10	0,02	0,30	0,36	0,06
Wheat	0,03	0,03	0,00	0,23	0,25	0,03
Other cereal grains	0,09	0,09	0,00	0,57	0,64	0,06
Vegetables and fruits	0,53	0,59	0,06	0,55	0,63	0,09
Oil seeds	0,04	0,03	0,00	0,36	0,39	0,03
Sugar cane and beet	0,01	0,01	0,00	0,47	0,53	0,07
Plant-based fibers	0,09	0,11	0,02	1,10	1,27	0,17
Other crops	0,02	0,01	0,00	0,37	0,40	0,03
Bovine cattle	0,04	0,04	0,01	0,54	0,63	0,09
Other animal products	0,78	0,84	0,07	0,91	1,02	0,11
Raw milk	0,00	0,00	0,00	0,12	0,15	0,03
Wool, silk-worm cocoos	0,02	0,02	0,00	0,44	0,49	0,05
Forestry	0,20	0,23	0,03	1,33	1,46	0,14
Fishing	0,48	0,55	0,07	1,74	1,95	0,21
Manufacturing	**89,10**	**88,12**	**-0,98**	**5,50**	**4,65**	**-0,85**
Coal	0,01	0,01	0,00	0,04	0,04	0,00
Oil	11,56	13,67	2,11	17,02	15,88	-1,14
Gas	0,41	0,41	0,00	22,44	20,00	-2,43
Electricity	42,88	38,11	-4,76	100,57	81,15	-19,42
Mining	0,48	0,54	0,05	1,25	1,16	-0,09
Bovine cattle, sheep	0,04	0,02	-0,02	1,30	0,78	-0,52
Other meat products	0,03	0,02	-0,01	0,17	0,14	-0,03
Vegetable oils and fats	0,29	0,21	-0,08	2,15	1,56	-0,59
Dairy products	0,02	0,01	0,00	1,33	0,97	-0,35
Processed rice	0,72	0,56	-0,17	1,59	1,22	-0,37
Sugar	0,01	0,00	0,00	0,81	0,37	-0,44
Other food products	0,18	0,11	-0,07	0,42	0,24	-0,17
Beverages and tobacco	0,61	0,57	-0,04	1,24	1,03	-0,21
Textiles	1,08	1,06	-0,02	0,78	0,66	-0,12
Wearing apparel	0,13	0,13	0,00	0,21	0,19	-0,02
Leather products	0,08	0,06	-0,02	0,18	0,15	-0,03
Wood	0,31	0,32	0,01	1,16	1,03	-0,13
Paper prod., publishing	0,97	0,98	0,00	2,01	1,77	-0,24
Chem. Prod., rub. plast.	11,42	12,11	0,69	6,10	5,34	-0,76
Other mineral products	7,96	8,57	0,60	6,30	5,66	-0,64
Ferrous metals	6,29	6,74	0,45	7,22	6,40	-0,82
Other metal	0,78	0,83	0,05	2,22	1,92	-0,30
Metal products	0,34	0,36	0,02	0,50	0,45	-0,05
Motor vehicles	0,29	0,30	0,01	0,70	0,61	-0,10
Other trans. equipment	0,16	0,17	0,01	0,50	0,45	-0,05
Electronic equipment	0,08	0,08	0,01	0,09	0,08	-0,01
Other mach. and equip.	1,48	1,60	0,12	0,65	0,58	-0,07
Other manufactures	0,49	0,53	0,04	0,71	0,61	-0,10
Water	0,03	0,03	0,00	0,53	0,46	-0,07
Construction	**0,38**	**0,45**	**0,07**	**0,15**	**0,15**	**0,00**
Services	**8,12**	**8,76**	**0,64**	**1,43**	**1,38**	**-0,05**
Trade	1,21	1,36	0,14	0,68	0,66	-0,02
Land transport	2,71	3,08	0,38	4,67	4,47	-0,19
Sea transport	0,72	0,89	0,16	9,86	9,50	-0,36
Air transport	0,41	0,50	0,09	4,42	4,18	-0,24
Communication	0,07	0,07	0,00	0,24	0,20	-0,04
Financial services	0,07	0,08	0,01	0,17	0,16	-0,01
Insurance	0,02	0,02	0,00	0,30	0,28	-0,02
Business services	0,32	0,32	0,00	0,97	0,85	-0,11
Recreation and other services	0,22	0,24	0,02	0,62	0,59	-0,03
Public services	2,36	2,20	-0,17	1,58	1,54	-0,05
Dwellinbgs	0,00	0,00	0,00	0,00	0,00	0,00
Total	**100,00**	**100,00**	**10,45**	**3,62**	**3,19**	**-0,43**

Table 10. Structure of energy consumption in 1997 and variation in 2000

Sector	Coal intensity (TCE/millon USD)		Oil intensity (TCE/millon USD)		Gas intensity (TCE/millon USD)		Electricity intensity (1000 kwh/millon USD)	
	1997	2000-1997	1997	2000-1997	1997	2000-1997	1997	2000-1997
Agriculture	**21,16**	**2,16**	**36,09**	**6,61**	**0,05**	**0,01**	**0,24**	**0,03**
Paddy rice	4,21	0,49	21,81	4,85	0,00	0,00	0,21	0,03
Wheat	3,19	0,13	16,70	2,33	0,00	0,00	0,16	0,01
Other cereal grains	7,44	0,26	42,92	5,75	0,00	0,00	0,37	0,03
Vegetables and fruits	7,70	0,61	39,84	7,26	0,00	0,00	0,39	0,05
Oil seeds	5,06	0,11	26,27	3,12	0,00	0,00	0,25	0,02
Sugar cane and beet	6,45	0,44	34,18	5,81	0,00	0,00	0,32	0,04
Plant-based fibers	15,28	1,23	80,40	14,80	0,00	0,00	0,76	0,09
Other crops	4,97	0,03	27,12	2,77	0,00	0,00	0,25	0,01
Bovine cattle	26,36	4,20	6,03	1,63	0,09	0,02	0,04	0,01
Other animal products	44,60	4,65	10,16	2,14	0,15	0,02	0,07	0,01
Raw milk	5,88	1,24	1,37	0,45	0,02	0,01	0,01	0,00
Wool, silk-worm cocoos	19,91	1,85	8,15	1,61	0,06	0,01	0,03	0,00
Forestry	47,82	3,28	44,85	7,67	0,05	0,01	0,21	0,02
Fishing	26,29	1,25	123,25	18,26	0,03	0,00	0,19	0,02
Manufacturing	**235,96**	**-45,55**	**119,07**	**-2,40**	**15,70**	**-1,62**	**0,63**	**-0,08**
Coal	2,37	-0,21	0,12	0,00	0,03	0,00	0,00	0,00
Oil	1,05	-0,17	1664,13	-111,09	0,03	0,00	0,00	0,00
Gas	1053,06	-129,21	324,32	-8,64	2392,50	-141,06	0,00	0,00
Electricity	5274,95	-1040,38	466,91	-51,04	166,36	-23,11	8,01	-1,32
Mining	63,42	-4,86	9,21	0,23	1,66	-0,02	0,58	-0,02
Bovine cattle, sheep	67,83	-27,56	6,95	-2,37	0,39	-0,14	0,45	-0,17
Other meat products	8,82	-1,78	0,96	-0,11	0,05	-0,01	0,06	-0,01
Vegetable oils and fats	113,93	-31,76	8,25	-1,65	1,46	-0,33	0,45	-0,11
Dairy products	68,91	-18,70	7,54	-1,44	0,40	-0,09	0,46	-0,11
Processed rice	84,22	-19,91	6,04	-0,92	1,08	-0,19	0,33	-0,07
Sugar	42,63	-23,34	3,25	-1,62	0,55	-0,28	0,17	-0,09
Other food products	21,92	-9,09	1,74	-0,61	0,28	-0,10	0,09	-0,03
Beverages and tobacco	66,44	-11,39	3,06	-0,25	1,23	-0,14	0,25	-0,04
Textiles	40,87	-6,35	3,60	-0,23	4,21	-0,40	0,32	-0,04
Wearing apparel	10,61	-1,11	1,77	-0,01	0,95	-0,04	0,08	-0,01
Leather products	8,53	-1,43	2,39	-0,18	0,53	-0,06	0,07	-0,01
Wood	60,76	-7,08	5,82	-0,11	1,38	-0,07	0,25	-0,02
Paper prod., publishing	106,06	-12,85	8,05	-0,20	0,35	-0,02	0,52	-0,04
Chem. Prod., rub. plast.	198,62	-32,08	243,89	-17,00	48,96	-4,93	0,91	-0,11
Other mineral products	327,96	-35,28	33,84	-0,33	4,56	-0,19	0,61	-0,04
Ferrous metals	372,44	-44,64	44,67	-1,05	17,17	-0,96	1,30	-0,11
Other metal	109,36	-15,84	22,55	-1,15	8,87	-0,73	1,52	-0,16
Metal products	25,29	-2,79	4,37	-0,06	2,97	-0,14	0,38	-0,03
Motor vehicles	34,62	-5,04	7,02	-0,36	1,50	-0,12	0,26	-0,03
Other trans. equipment	25,11	-2,78	4,23	-0,06	1,30	-0,06	0,28	-0,02
Electronic equipment	4,13	-0,48	1,46	-0,03	2,13	-0,11	0,06	0,00
Other mach. and equip.	32,75	-3,67	5,05	-0,07	3,10	-0,15	0,13	-0,01
Other manufactures	36,70	-5,21	4,07	-0,20	3,96	-0,32	0,20	-0,02
Water	15,23	-2,73	25,29	-2,26	0,34	-0,04	4,15	-0,56
Construction	**5,41**	**-0,29**	**4,95**	**0,25**	**0,68**	**0,01**	**0,08**	**0,00**
Services	**23,19**	**-3,37**	**98,56**	**1,41**	**0,84**	**-0,09**	**0,16**	**-0,02**
Trade	9,42	-0,95	49,47	-0,09	0,18	-0,01	0,07	0,00
Land transport	41,11	-5,03	383,92	-10,05	0,09	-0,01	0,12	-0,01
Sea transport	1,92	-0,25	962,07	-34,88	0,03	0,00	0,01	0,00
Air transport	0,96	-0,14	430,88	-23,43	0,01	0,00	0,01	0,00
Communication	0,00	0,00	23,78	-3,84	1,36	-0,26	0,45	-0,09
Financial services	2,94	-0,37	11,12	-0,35	0,73	-0,05	0,08	-0,01
Insurance	5,85	-0,81	19,16	-0,84	0,73	-0,06	0,09	-0,01
Business services	41,95	-5,78	20,10	-0,87	1,08	-0,08	0,16	-0,01
Recreation and other services	22,43	-1,82	20,97	0,41	0,71	-0,01	0,10	0,00
Public services	45,05	-3,52	74,87	1,71	2,03	-0,02	0,33	-0,01
Dwellinbgs	0,26	-0,03	0,01	0,00	0,02	0,00	0,00	0,00
Total	**146,11**	**-24,10**	**94,75**	**0,80**	**9,45**	**-0,71**	**0,44**	**-0,04**

Similar to the gross output composition, China's export and import structure also shows the dominant place of her industry sector. Generally speaking, over 15% of her industrial products are exported and over 15% of the industrial goods in domestic market come from other countries. Comparing the export and import structure in each industrial sector shows China's comparative advantage in trade stays in the traditional or emerging labor-intensive industries such as textile, wearing apparel, leather goods and electronic equipment sectors. In addition, her significant import ratio in oil and petroleum, food, ferrous metal products and that in chemical products, motor vehicle and other machinery and equipment sectors manifest his constraint in natural resource endowment *vis-à-vis* to his population and economy scale and her relatively retarded position in some capital- intensive industries, respectively. Though during 1997-2000, most of the sectors show relatively stable share in total production and international trade, we still find two interesting facts. Firstly, the obvious reduction in agriculture export and the important increase in their import ratio, along with the significant increase of import in food production industries, in fact reveal an amelioration tendency in people's live since the population growth stays relatively stably at 1% during these years. Secondly, during 1997-2000, we observe important export ratio in natural gas industry. Given the zero SO_2-effluent rate of natural gas as energy, we expect it to be a potential and important substitute for coal combustion in China's energy composition.

Table 9 shows the SO_2 emission situation during 1997-2000. Since we are interested in the direct link between energy consumption and SO_2 emission, we show following in Table 10 the consumption situation of the four principal energy inputs in China. Clearly, confirming to the commonly agreed fact, China's SO_2 pollution problem comes principally from coal combustion, especially that in industrial sectors. The sectors have most serious SO_2 share are generally the industries that consume most intensively coal in their production activities, such as electricity generation, chemical products, metal products and other mineral products sectors. While the other principal source of SO_2 emission comes from oil combustion, whose consumption is generally concentrated in oil and petroleum, chemical products, electricity and the three transportation service sectors. Due to the ever-strengthening efforts in SO_2 pollution control, we observe the general declining tendency in SO_2 emission intensity in all industrial and service sectors where the de-sulfur policy are applied. (On the contrary, SO_2 and energy intensity of agriculture sectors shows slight increase since emission levy system was not exerted.) This SO_2 intensity reduction tendency could be explained by the general energy intensity decline shown in Table 10. Among the four principal energies, the most obvious intensity reduction in coal combustion in fact reveals the energy composition transformation for most industrial and service sector, whose dependence on coal reduces rapidly. Furthermore, the most important sulfur reduction was also achieved in the most SO_2-polluting sectors, especially in electricity generation sector, whose SO_2 emission reduction, achieved by very important intensity reduction (-19.42%), contributed principally to the reduction of industrial SO_2 emission share during 1997-2000. However, given the significant economy growth, on absolute term, the total SO_2 emission and total energy consumption still increased between 1997-2000, though the pollution controlling efforts were exerted. This should be explained by the cancellation of intensity reduction effect by the actual enlargement of production scale. (Compare Table 7 and 10.)

Table 11. Output changes (percentage change in 2005 from the reference simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**7,91**	**0,09**	**-0,17**	**-0,08**
Paddy rice	12,21	-0,09	-2,81	-2,86
Wheat	-6,23	0,65	24,91	25,23
Other cereal grains	-3,79	0,55	-4,08	-3,49
Vegetables and fruits	6,38	0,09	-1,20	-1,12
Oil seeds	-9,87	0,76	-23,36	-22,41
Sugar cane and beet	1,88	0,00	-4,74	-4,82
Plant-based fibers	7,11	-0,05	0,57	0,52
Other crops	-10,81	0,84	-10,18	-9,20
Bovine cattle	13,52	0,12	-0,36	-0,22
Other animal products	7,05	0,26	-1,10	-0,82
Raw milk	15,68	0,12	-0,59	-0,45
Wool, silk-worm cocoos	-0,19	0,73	-3,56	-2,75
Forestry	18,28	-0,60	-5,62	-6,17
Fishing	17,10	-0,09	-1,79	-1,87
Manufacturing	**45,55**	**-1,37**	**1,05**	**-0,39**
Coal	11,80	-25,88	0,80	-25,90
Oil	70,10	-7,44	1,48	-6,62
Gas	37,11	1,10	1,82	2,73
Electricity	41,78	-2,83	2,40	-0,63
Mining	51,48	-1,69	-2,42	-4,25
Bovine cattle, sheep	-41,79	2,87	-6,84	-3,82
Other meat products	-5,58	0,81	-7,72	-6,85
Vegetable oils and fats	9,14	-0,72	-9,12	-9,90
Dairy products	-5,00	0,60	-7,25	-6,59
Processed rice	8,89	0,18	-3,56	-3,30
Sugar	-40,61	3,11	-20,70	-17,72
Other food products	-2,80	0,60	-13,53	-12,79
Beverages and tobacco	31,48	-0,34	-8,51	-8,73
Textiles	42,02	-0,10	5,36	5,28
Wearing apparel	40,78	1,16	34,39	36,16
Leather products	-25,75	1,99	4,05	6,45
Wood	43,64	-0,08	-1,65	-1,70
Paper prod., publishing	40,54	-0,64	-6,91	-7,57
Chem. Prod., rub. plast.	52,57	-3,78	-1,28	-5,53
Other mineral products	52,86	-1,24	-0,21	-1,55
Ferrous metals	56,32	-2,95	-3,57	-6,81
Other metal	60,54	-2,52	-3,93	-6,68
Metal products	53,26	-1,19	-0,41	-1,68
Motor vehicles	54,90	-0,95	-7,69	-8,66
Other trans. equipment	57,64	-0,65	0,82	0,16
Electronic equipment	66,88	0,46	5,38	5,88
Other mach. and equip.	57,23	-0,63	-2,01	-2,64
Other manufactures	65,53	-0,11	1,73	1,61
Water	58,64	-2,01	0,07	-2,07
Construction	**51,25**	**-0,59**	**1,93**	**1,33**
Services	**40,08**	**-0,53**	**0,29**	**-0,27**
Trade	43,34	-0,32	-0,04	-0,37
Land transport	54,77	-1,22	-0,70	-2,00
Sea transport	83,05	-5,15	1,62	-3,96
Air transport	82,43	-1,63	1,70	-0,05
Communication	63,37	-0,54	0,98	0,42
Financial services	53,19	-0,55	-0,25	-0,83
Insurance	57,09	-0,09	-0,78	-0,87
Business services	39,89	-0,35	-0,33	-0,70
Recreation and other services	43,67	-0,51	0,34	-0,18
Public services	11,23	-0,15	-0,25	-0,40
Dwellinbgs	80,95	-0,08	0,42	0,34
Total	**38,07**	**-0,87**	**0,61**	**-0,30**

Table 12. SO_2 emission changes (percentage change in 2005 from the reference simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**28,81**	**4,57**	**-0,62**	**4,14**
Paddy rice	46,43	2,46	-3,59	-0,97
Wheat	7,89	3,57	46,82	51,67
Other cereal grains	11,97	3,26	-3,60	-0,23
Vegetables and fruits	30,40	2,93	0,11	3,21
Oil seeds	2,66	3,70	-26,73	-23,56
Sugar cane and beet	21,56	2,64	-5,28	-2,74
Plant-based fibers	28,67	3,23	3,12	6,66
Other crops	2,03	3,62	-10,79	-7,16
Bovine cattle	39,84	8,11	0,81	9,37
Other animal products	21,91	8,35	-0,33	8,34
Raw milk	51,16	8,16	-0,06	8,47
Wool, silk-worm cocoos	9,49	8,12	-3,93	4,24
Forestry	33,44	5,13	-4,69	0,44
Fishing	38,66	1,45	-0,51	1,02
Manufacturing	**18,35**	**-27,30**	**1,06**	**-27,41**
Coal	-2,02	-56,01	2,03	-56,27
Oil	49,93	-11,08	2,08	-10,02
Gas	13,62	-34,13	2,69	-33,53
Electricity	1,83	-28,88	2,69	-27,85
Mining	31,26	-38,45	-2,21	-40,91
Bovine cattle, sheep	-65,54	-34,36	-6,57	-39,30
Other meat products	-27,11	-37,03	-7,40	-42,58
Vegetable oils and fats	-27,76	-34,07	-10,57	-42,00
Dairy products	-40,26	-36,33	-7,99	-42,28
Processed rice	-21,07	-36,90	-3,11	-39,82
Sugar	-65,65	-34,13	-22,24	-49,24
Other food products	-42,29	-36,59	-16,48	-47,76
Beverages and tobacco	-1,84	-37,12	-9,19	-43,80
Textiles	10,24	-37,96	9,06	-33,47
Wearing apparel	18,68	-36,50	50,84	-5,35
Leather products	-41,26	-34,23	6,35	-30,83
Wood	17,76	-37,30	-0,72	-38,76
Paper prod., publishing	15,15	-37,58	-7,21	-43,09
Chem. Prod., rub. plast.	24,53	-26,20	-0,81	-27,82
Other mineral products	26,97	-36,55	1,01	-37,02
Ferrous metals	28,84	-37,08	-3,32	-40,38
Other metal	28,56	-36,51	-4,09	-40,21
Metal products	27,78	-38,07	0,83	-38,62
Motor vehicles	23,65	-37,12	-10,67	-44,75
Other trans. equipment	31,03	-37,61	2,51	-37,06
Electronic equipment	40,60	-34,57	10,93	-28,40
Other mach. and equip.	30,58	-37,71	-1,81	-39,83
Other manufactures	28,21	-37,81	4,33	-36,21
Water	25,83	-21,78	1,30	-21,34
Construction	**39,77**	**-28,36**	**4,27**	**-26,01**
Services	**34,28**	**-14,40**	**1,67**	**-13,44**
Trade	33,71	-13,81	1,92	-12,54
Land transport	42,04	-11,20	0,59	-11,09
Sea transport	70,85	-9,54	3,12	-7,33
Air transport	66,36	-6,51	4,04	-3,12
Communication	27,79	-4,92	3,65	-1,65
Financial services	35,64	-16,03	1,42	-15,27
Insurance	36,98	-16,58	0,31	-16,74
Business services	14,71	-32,91	1,04	-33,06
Recreation and other services	29,59	-28,08	2,19	-27,21
Public services	5,06	-22,44	1,70	-21,69
Dwellinbgs	40,34	-36,72	0,84	-37,27
Total	**20,12**	**-25,13**	**1,09**	**-25,13**

Table 13. Coal intermediary consumption changes (percentage change in 2005 from simulation BAU)

Sector	BAU	DESULFUR	LIB	LIB+DESULFUR
	Change from 2000	Change from BAU	Change from BAU	Change from BAU
Agriculture	**19,20**	**10,30**	**-1,16**	**9,43**
Paddy rice	28,10	11,47	-4,39	7,09
Wheat	-5,65	12,70	45,60	64,06
Other cereal grains	-2,35	12,55	-4,42	8,09
Vegetables and fruits	14,08	11,98	-0,72	11,61
Oil seeds	-10,20	12,82	-27,34	-17,33
Sugar cane and beet	6,27	11,71	-6,07	5,22
Plant-based fibers	12,51	12,34	2,26	15,38
Other crops	-10,88	12,84	-11,53	0,49
Bovine cattle	36,66	9,72	0,66	10,89
Other animal products	19,15	9,96	-0,48	9,83
Raw milk	47,67	9,80	-0,21	9,99
Wool, silk-worm cocoos	5,50	10,73	-4,16	6,58
Forestry	24,85	9,69	-5,10	4,49
Fishing	21,66	10,16	-1,32	9,06
Manufacturing	**9,56**	**-36,79**	**0,84**	**-37,33**
Coal	-2,59	-57,21	1,99	-57,55
Oil	26,38	-49,23	1,06	-50,20
Gas	10,30	-42,20	2,50	-42,20
Electricity	0,85	-32,03	2,62	-31,27
Mining	29,26	-42,64	-2,30	-45,21
Bovine cattle, sheep	-65,92	-37,67	-6,64	-42,57
Other meat products	-27,96	-40,38	-7,47	-45,85
Vegetable oils and fats	-28,34	-36,50	-10,62	-44,29
Dairy products	-40,97	-39,72	-8,06	-45,58
Processed rice	-21,69	-39,21	-3,16	-42,18
Sugar	-65,94	-36,69	-22,28	-51,35
Other food products	-42,79	-39,12	-16,53	-50,00
Beverages and tobacco	-2,35	-38,64	-9,22	-45,26
Textiles	9,18	-40,69	8,99	-36,61
Wearing apparel	16,63	-41,35	50,67	-13,07
Leather products	-42,85	-41,76	6,16	-39,27
Wood	16,54	-40,27	-0,79	-41,87
Paper prod., publishing	14,19	-39,98	-7,26	-45,43
Chem. Prod., rub. plast.	15,21	-45,66	-1,29	-47,87
Other mineral products	25,55	-39,77	0,94	-40,44
Ferrous metals	27,19	-40,72	-3,40	-44,06
Other metal	25,88	-42,26	-4,22	-45,99
Metal products	25,50	-42,93	0,71	-43,77
Motor vehicles	21,12	-42,74	-10,79	-50,02
Other trans. equipment	28,74	-42,41	2,40	-42,24
Electronic equipment	36,02	-43,38	10,69	-38,66
Other mach. and equip.	28,48	-42,17	-1,91	-44,43
Other manufactures	26,68	-41,17	4,25	-39,89
Water	14,92	-44,71	0,74	-45,58
Construction	**30,90**	**-45,05**	**3,84**	**-44,21**
Services	**7,79**	**-45,46**	**0,81**	**-46,28**
Trade	16,99	-46,07	1,10	-46,75
Land transport	22,53	-46,41	-0,29	-47,88
Sea transport	44,06	-48,31	2,09	-48,68
Air transport	40,29	-46,56	3,00	-46,34
Communication	6,90	-45,16	3,23	-45,16
Financial services	19,93	-45,97	0,67	-46,88
Insurance	21,74	-45,56	-0,40	-47,03
Business services	9,99	-43,95	0,78	-44,75
Recreation and other services	21,26	-45,00	1,76	-45,29
Public services	-4,05	-45,19	1,14	-45,83
Dwellinbgs	39,54	-38,40	0,80	-39,06
Total	**9,77**	**-36,14**	**0,82**	**-36,69**

Table 14. Oil intermediary consumption changes (percentage change in 2005 from simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**38,14**	**-0,23**	**-0,17**	**-0,29**
Paddy rice	52,18	0,08	-3,37	-3,10
Wheat	12,08	1,19	47,14	48,45
Other cereal grains	16,00	1,06	-3,41	-2,19
Vegetables and fruits	35,52	0,55	0,33	0,99
Oil seeds	6,68	1,30	-26,57	-25,20
Sugar cane and beet	26,24	0,30	-5,08	-4,79
Plant-based fibers	33,66	0,87	3,34	4,40
Other crops	5,87	1,32	-10,60	-9,07
Bovine cattle	62,35	-1,49	1,73	0,33
Other animal products	41,55	-1,27	0,57	-0,62
Raw milk	75,43	-1,42	0,84	-0,48
Wool, silk-worm cocoos	25,33	-0,58	-3,15	-3,56
Forestry	48,31	-1,51	-4,10	-5,46
Fishing	44,53	-1,09	-0,28	-1,32
Manufacturing	**43,87**	**-6,35**	**1,54**	**-5,50**
Coal	15,57	-25,04	3,02	-23,27
Oil	49,95	-11,05	2,08	-9,99
Gas	30,87	1,26	3,53	4,48
Electricity	19,66	19,09	3,66	24,25
Mining	53,36	0,50	-1,31	-0,96
Bovine cattle, sheep	-59,57	9,24	-5,69	3,81
Other meat products	-14,53	4,46	-6,53	-2,10
Vegetable oils and fats	-14,97	11,27	-9,72	0,72
Dairy products	-29,96	5,61	-7,13	-1,62
Processed rice	-7,09	6,51	-2,18	4,52
Sugar	-59,60	11,10	-21,49	-11,93
Other food products	-32,13	6,64	-15,68	-9,63
Beverages and tobacco	15,86	7,49	-8,30	-1,04
Textiles	29,55	3,91	10,09	14,59
Wearing apparel	38,38	2,76	52,19	57,14
Leather products	-32,19	2,03	7,23	9,79
Wood	38,27	4,64	0,22	5,08
Paper prod., publishing	35,48	5,15	-6,33	-1,36
Chem. Prod., rub. plast.	36,69	-4,79	-0,29	-5,77
Other mineral products	48,97	5,52	1,96	7,67
Ferrous metals	50,91	3,86	-2,42	1,11
Other metal	49,36	1,15	-3,25	-2,37
Metal products	48,91	-0,02	1,73	1,65
Motor vehicles	43,71	0,32	-9,89	-9,65
Other trans. equipment	52,75	0,89	3,43	4,41
Electronic equipment	61,39	-0,81	11,81	10,89
Other mach. and equip.	52,44	1,31	-0,92	0,45
Other manufactures	50,30	3,07	5,30	8,65
Water	36,35	-3,14	1,76	-1,63
Construction	**55,31**	**-3,73**	**4,89**	**0,85**
Services	**43,61**	**-6,19**	**1,90**	**-4,76**
Trade	38,81	-5,52	2,13	-3,75
Land transport	45,39	-6,11	0,71	-5,77
Sea transport	70,93	-9,44	3,12	-7,22
Air transport	66,45	-6,38	4,04	-2,99
Communication	27,79	-4,92	3,65	-1,65
Financial services	42,29	-5,34	1,69	-3,97
Insurance	44,44	-4,63	0,60	-4,25
Business services	30,51	-1,80	1,80	-0,13
Recreation and other services	43,87	-3,64	2,79	-1,10
Public services	13,85	-3,97	2,16	-2,07
Dwellinbgs	65,57	7,92	1,82	10,16
Total	**43,62**	**-6,04**	**1,56**	**-5,08**

Table 15. Gas intermediary consumption changes (percentage change in 2005 from simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**33,21**	**-4,23**	**-0,54**	**-4,89**
Paddy rice	41,95	-2,92	-4,12	-7,04
Wheat	4,32	-1,78	46,15	42,60
Other cereal grains	8,42	-2,05	-4,34	-6,16
Vegetables and fruits	26,52	-2,45	-0,50	-3,08
Oil seeds	0,00	-1,88	-27,50	-28,13
Sugar cane and beet	19,23	-3,23	-6,45	-6,45
Plant-based fibers	24,62	-2,12	2,47	0,18
Other crops	-1,25	-1,27	-11,39	-12,66
Bovine cattle	51,56	-4,45	0,89	-3,71
Other animal products	32,14	-4,24	-0,26	-4,63
Raw milk	63,75	-4,36	0,02	-4,48
Wool, silk-worm cocoos	16,99	-3,57	-3,95	-7,45
Forestry	38,45	-4,47	-4,89	-9,27
Fishing	34,92	-4,06	-1,10	-5,30
Manufacturing	**24,58**	**8,77**	**0,78**	**9,89**
Coal	7,91	-21,11	2,17	-19,68
Oil	40,00	-6,39	1,24	-5,79
Gas	22,19	6,57	2,68	9,35
Electricity	11,72	25,32	2,80	30,04
Mining	43,19	5,76	-2,13	3,66
Bovine cattle, sheep	-62,25	14,96	-6,47	8,64
Other meat products	-20,20	9,94	-7,30	2,46
Vegetable oils and fats	-20,62	17,09	-10,46	5,41
Dairy products	-34,60	11,14	-7,90	2,98
Processed rice	-13,26	12,08	-2,99	9,39
Sugar	-62,27	16,88	-22,14	-7,86
Other food products	-36,63	12,24	-16,38	-5,40
Beverages and tobacco	8,17	13,12	-9,06	3,57
Textiles	20,95	9,35	9,18	19,94
Wearing apparel	29,20	8,14	50,93	64,47
Leather products	-36,69	7,37	6,35	14,91
Wood	29,10	10,12	-0,61	9,98
Paper prod., publishing	26,49	10,66	-7,10	3,24
Chem. Prod., rub. plast.	27,62	0,19	-1,11	-1,38
Other mineral products	39,08	11,05	1,11	12,69
Ferrous metals	40,90	9,30	-3,23	5,83
Other metal	39,45	6,45	-4,05	2,18
Metal products	39,03	5,21	0,89	6,39
Motor vehicles	34,17	5,57	-10,63	-5,43
Other trans. equipment	42,62	6,17	2,58	9,28
Electronic equipment	50,68	4,38	10,89	16,06
Other mach. and equip.	42,32	6,62	-1,74	5,13
Other manufactures	40,33	8,47	4,43	13,72
Water	27,30	1,93	0,92	2,96
Construction	**45,01**	**1,31**	**4,03**	**5,55**
Services	**14,74**	**0,91**	**1,37**	**2,39**
Trade	29,60	-0,57	1,28	0,74
Land transport	35,74	-1,20	-0,12	-1,38
Sea transport	59,59	-4,69	2,27	-2,89
Air transport	55,42	-1,48	3,18	1,53
Communication	19,31	0,06	2,79	2,93
Financial services	32,85	-0,38	0,85	0,50
Insurance	34,86	0,37	-0,23	0,22
Business services	21,85	3,35	0,95	4,53
Recreation and other services	34,32	1,41	1,94	3,51
Public services	6,29	1,06	1,32	2,50
Dwellinbgs	54,59	13,57	0,98	15,30
Total	**24,57**	**8,57**	**0,81**	**9,72**

Table 16. Electricity intermediary consumption changes (percentage change in 2005 from simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**24,10**	**1,56**	**1,54**	**3,24**
Paddy rice	39,69	1,35	-1,95	-0,44
Wheat	2,88	2,48	49,31	52,53
Other cereal grains	6,49	2,34	-1,99	0,49
Vegetables and fruits	24,40	1,82	1,81	3,77
Oil seeds	-2,07	2,59	-25,49	-23,14
Sugar cane and beet	15,88	1,58	-3,68	-2,18
Plant-based fibers	22,69	2,15	4,86	7,27
Other crops	-2,81	2,60	-9,28	-6,58
Bovine cattle	47,31	0,49	3,15	3,78
Other animal products	28,43	0,71	1,98	2,80
Raw milk	59,20	0,55	2,26	2,94
Wool, silk-worm cocoos	14,20	1,15	-1,76	-0,49
Forestry	35,71	-0,06	-2,70	-2,68
Fishing	32,66	0,17	1,19	1,40
Manufacturing	**22,13**	**8,48**	**2,46**	**11,53**
Coal	3,50	-25,69	4,39	-22,88
Oil	37,77	-4,07	3,59	-1,10
Gas	18,72	8,08	4,93	13,43
Electricity	7,67	20,01	5,06	27,05
Mining	38,62	2,72	0,05	2,81
Bovine cattle, sheep	-63,58	10,35	-4,41	6,43
Other meat products	-22,95	5,73	-5,26	0,58
Vegetable oils and fats	-23,64	11,30	-8,51	2,20
Dairy products	-36,86	6,90	-5,87	1,09
Processed rice	-16,57	6,51	-0,87	6,03
Sugar	-63,70	11,28	-20,44	-10,51
Other food products	-39,00	6,97	-14,55	-8,03
Beverages and tobacco	3,66	6,31	-7,10	-0,79
Textiles	16,60	5,23	11,57	17,79
Wearing apparel	25,23	5,73	54,29	64,26
Leather products	-38,37	6,28	8,75	16,26
Wood	24,50	5,62	1,57	7,64
Paper prod., publishing	21,71	5,25	-5,07	0,15
Chem. Prod., rub. plast.	25,14	1,67	1,16	2,45
Other mineral products	34,22	6,68	3,34	10,48
Ferrous metals	36,17	5,68	-1,09	4,46
Other metal	35,41	4,62	-1,90	2,61
Metal products	34,80	3,07	3,13	6,46
Motor vehicles	30,27	3,58	-8,63	-5,20
Other trans. equipment	38,25	3,68	4,86	9,00
Electronic equipment	46,78	4,54	13,38	18,86
Other mach. and equip.	37,86	4,05	0,44	4,79
Other manufactures	35,55	5,02	6,73	12,40
Water	24,97	3,63	3,25	7,17
Construction	**42,08**	**2,46**	**6,41**	**9,25**
Services	**15,19**	**2,36**	**3,68**	**6,30**
Trade	27,44	1,63	3,63	5,45
Land transport	33,52	1,10	2,20	3,36
Sea transport	57,05	-2,33	4,65	1,93
Air transport	52,93	0,96	5,58	6,58
Communication	17,39	2,56	5,18	8,06
Financial services	30,57	1,74	3,19	5,11
Insurance	32,53	2,43	2,08	4,74
Business services	19,05	3,42	3,25	7,01
Recreation and other services	31,65	2,53	4,29	7,12
Public services	4,35	2,75	3,65	6,69
Dwellinbgs	48,39	7,86	3,16	11,66
Total	**22,14**	**7,44**	**2,57**	**10,55**

Table 17. Export changes (percentage change in 2005 from the reference simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**-62,72**	**3,64**	**5,21**	**9,17**
Paddy rice	-88,09	7,41	24,65	33,30
Wheat	-54,61	3,12	-77,79	-76,97
Other cereal grains	-56,15	2,48	6,76	9,49
Vegetables and fruits	-73,52	4,03	0,66	4,86
Oil seeds	-53,25	3,48	41,65	47,81
Sugar cane and beet	-67,34	5,19	17,89	24,46
Plant-based fibers	-54,65	0,18	-3,40	-3,27
Other crops	-55,16	3,74	11,95	16,46
Bovine cattle	-89,14	5,24	-2,83	1,99
Other animal products	-72,73	4,15	1,53	5,72
Raw milk	-94,04	4,75	2,03	6,57
Wool, silk-worm cocoos	-67,32	2,91	10,86	14,20
Forestry	-60,39	5,51	-6,38	-1,21
Fishing	-57,58	3,89	0,22	4,12
Manufacturing	**53,00**	**-1,62**	**14,06**	**12,37**
Coal	-13,84	8,05	3,29	11,96
Oil	172,33	-13,11	6,75	-7,70
Gas	57,77	-13,95	4,85	-10,51
Electricity	271,07	-57,59	6,24	-56,92
Mining	26,96	0,59	5,23	5,75
Bovine cattle, sheep	-82,35	6,52	-6,18	0,05
Other meat products	-69,10	4,44	-3,91	0,40
Vegetable oils and fats	-24,82	-0,34	39,23	38,32
Dairy products	-33,43	2,55	-3,03	-0,59
Processed rice	-66,43	5,12	13,76	19,19
Sugar	-77,67	7,71	-4,50	3,85
Other food products	-60,10	3,64	-25,43	-22,39
Beverages and tobacco	-20,34	1,59	0,72	2,33
Textiles	40,93	-0,01	39,31	39,11
Wearing apparel	35,68	2,72	74,72	78,58
Leather products	-52,65	4,43	17,16	22,56
Wood	23,68	1,36	7,22	8,58
Paper prod., publishing	28,93	-0,16	5,32	4,98
Chem. Prod., rub. plast.	72,87	-8,72	10,21	-0,08
Other mineral products	58,25	-4,43	4,66	-0,29
Ferrous metals	64,49	-9,44	5,21	-5,41
Other metal	70,40	-6,35	6,42	-0,88
Metal products	58,20	-2,22	6,89	4,43
Motor vehicles	79,05	-0,96	17,40	15,95
Other trans. equipment	62,98	-0,10	9,59	9,46
Electronic equipment	70,89	0,84	19,23	20,13
Other mach. and equip.	65,62	-0,01	10,43	10,36
Other manufactures	76,08	0,94	6,78	7,69
Water	176,04	-8,71	1,69	-7,71
Construction	**29,23**	**0,97**	**3,63**	**4,68**
Services	**78,38**	**-0,72**	**1,12**	**0,26**
Trade	24,53	3,34	2,70	6,12
Land transport	88,65	-0,72	1,13	0,28
Sea transport	124,48	-7,75	4,06	-4,34
Air transport	123,11	-2,23	4,08	1,68
Communication	234,21	1,77	5,79	7,65
Financial services	84,05	4,78	0,75	5,66
Insurance	90,95	3,20	3,31	6,61
Business services	47,92	2,74	3,19	6,02
Recreation and other services	30,70	2,12	8,90	11,25
Public services	-10,35	2,20	-0,77	1,41
Dwellinbgs	150,00	0,00	0,00	20,00
Total	**54,00**	**-1,51**	**12,70**	**11,12**

Table 18. Import changes (percentage change in 2005 from the reference simulation BAU)

Sector	BAU Change from 2000	DESULFUR Change from BAU	LIB Change from BAU	LIB+DESULFUR Change from BAU
Agriculture	**196,25**	**-3,02**	**-23,52**	**-25,84**
Paddy rice	958,09	-7,06	-10,90	-16,79
Wheat	93,86	-1,77	-97,23	-97,32
Other cereal grains	118,99	-1,40	14,83	13,28
Vegetables and fruits	330,11	-3,71	-34,95	-37,46
Oil seeds	76,76	-1,94	36,96	34,37
Sugar cane and beet	218,06	-4,94	-9,74	-14,66
Plant-based fibers	153,03	-0,29	11,81	11,54
Other crops	125,56	-2,56	4,46	1,79
Bovine cattle	1089,57	-4,80	20,81	15,44
Other animal products	323,93	-3,50	17,46	13,42
Raw milk	2146,66	-4,36	13,52	8,99
Wool, silk-worm cocoos	206,48	-1,41	18,91	17,35
Forestry	254,95	-6,37	16,18	8,79
Fishing	227,80	-3,95	38,44	32,99
Manufacturing	**49,71**	**-0,19**	**23,44**	**23,22**
Coal	52,00	-52,77	19,96	-44,75
Oil	-8,40	1,24	15,14	15,94
Gas	10,29	29,78	16,44	52,89
Electricity	-48,86	134,78	14,93	182,66
Mining	81,79	-3,98	6,20	1,67
Bovine cattle, sheep	98,15	-0,72	28,66	28,57
Other meat products	204,42	-2,77	31,01	27,65
Vegetable oils and fats	62,34	-1,12	28,51	27,11
Dairy products	39,73	-1,44	28,39	26,89
Processed rice	255,57	-4,53	169,67	158,75
Sugar	89,26	-1,70	15,91	14,11
Other food products	163,04	-2,54	55,92	52,12
Beverages and tobacco	120,41	-2,28	190,90	184,78
Textiles	43,60	-0,23	64,14	64,20
Wearing apparel	55,57	-2,91	63,34	59,27
Leather products	98,98	-2,21	22,45	19,95
Wood	76,32	-1,96	36,14	33,63
Paper prod., publishing	54,25	-1,16	25,39	23,99
Chem. Prod., rub. plast.	29,58	3,19	15,72	19,31
Other mineral products	47,10	2,43	43,44	47,14
Ferrous metals	47,53	4,97	18,32	24,28
Other metal	49,49	2,27	12,06	14,64
Metal products	47,09	0,16	29,32	29,48
Motor vehicles	32,07	-0,94	58,44	57,10
Other trans. equipment	50,96	-1,37	13,67	12,11
Electronic equipment	56,53	-0,59	18,94	18,31
Other mach. and equip.	46,02	-1,53	21,46	19,62
Other manufactures	41,93	-2,80	47,32	43,22
Water	-9,36	5,29	15,43	21,95
Construction	**77,13**	**-2,13**	**17,56**	**15,00**
Services	**41,48**	**-3,16**	**2,89**	**-0,38**
Trade	66,96	-4,12	13,84	9,12
Land transport	21,45	-1,83	13,59	11,44
Sea transport	3,49	3,68	10,04	14,10
Air transport	-5,98	0,76	8,42	9,23
Communication	-27,97	-3,31	11,81	8,04
Financial services	27,33	-5,66	15,80	9,07
Insurance	23,36	-4,15	10,47	5,83
Business services	31,47	-3,70	12,41	8,20
Recreation and other services	58,06	-3,10	8,33	4,92
Public services	38,38	-2,47	17,59	14,69
Dwellinbgs	0,00	0,00	0,00	0,00
Total	**57,68**	**-0,73**	**18,00**	**17,22**

Table 19. Trade balance change (real value, millon US$ 1997)

Sector	1997 (real value)	2000 (real value)	BAU (Δ from 2000)	DESULFUR (Δ from 2000)	LIB (Δ from 2000)	LIB+DESULFUR (Δ from 2000)
Agriculture	**-0,09**	**-10,94**	**-43,21**	**-41,76**	**-44,84**	**-43,31**
Paddy rice	0,10	0,02	-0,08	-0,07	-0,07	-0,06
Wheat	-0,35	-0,71	-1,39	-1,37	-0,04	-0,04
Other cereal grains	0,55	-0,19	-1,35	-1,32	-1,47	-1,43
Vegetables and fruits	0,68	-1,16	-7,15	-6,87	-4,54	-4,35
Oil seeds	-0,60	-1,31	-2,54	-2,48	-3,42	-3,35
Sugar cane and beet	0,00	0,00	0,00	0,00	0,00	0,00
Plant-based fibers	-1,39	-2,85	-7,22	-7,20	-8,07	-8,05
Other crops	0,84	0,09	-1,26	-1,21	-1,13	-1,06
Bovine cattle	0,05	-0,02	-0,41	-0,39	-0,50	-0,48
Other animal products	0,69	-1,35	-8,25	-7,94	-9,64	-9,29
Raw milk	0,00	-0,03	-0,62	-0,59	-0,70	-0,68
Wool, silk-worm cocoos	-0,35	-1,22	-3,81	-3,75	-4,52	-4,46
Forestry	-0,80	-2,35	-8,56	-8,01	-9,94	-9,30
Fishing	0,49	0,14	-0,58	-0,54	-0,80	-0,75
Manufacturing	**26,05**	**39,17**	**68,38**	**62,29**	**257,44**	**244,20**
Coal	1,15	1,09	0,87	1,04	1,30	1,53
Oil	-6,07	-2,23	11,01	8,33	19,56	15,49
Gas	0,26	0,36	0,56	0,49	0,83	0,71
Electricity	0,21	0,53	1,98	0,84	2,96	1,20
Mining	-2,00	-3,28	-6,40	-6,09	-6,37	-6,03
Bovine cattle, sheep	-0,24	-0,32	-0,74	-0,74	-0,96	-0,95
Other meat products	0,31	-1,28	-5,69	-5,52	-7,44	-7,23
Vegetable oils and fats	-2,53	-3,65	-6,38	-6,30	-7,94	-7,85
Dairy products	-0,21	-0,19	-0,32	-0,31	-0,40	-0,39
Processed rice	0,16	0,01	-0,75	-0,70	-2,10	-2,01
Sugar	-0,12	-0,28	-0,69	-0,67	-0,79	-0,78
Other food products	2,02	0,44	-7,38	-7,10	-12,29	-11,89
Beverages and tobacco	0,01	-0,51	-2,67	-2,57	-9,05	-8,82
Textiles	1,71	2,89	3,44	3,52	17,61	17,48
Wearing apparel	24,68	29,92	40,06	41,39	101,82	104,39
Leather products	18,50	15,39	1,43	2,00	5,61	6,49
Wood	2,70	2,72	2,21	2,37	3,90	4,11
Paper prod., publishing	-5,16	-6,78	-10,98	-10,82	-13,17	-13,00
Chem. Prod., rub. plast.	-14,65	-10,87	-3,40	-8,59	12,82	4,99
Other mineral products	1,93	2,58	4,57	3,93	6,96	5,96
Ferrous metals	-5,16	-6,34	-8,35	-10,16	-7,00	-9,53
Other metal	-3,59	-4,31	-5,75	-6,37	-4,29	-5,17
Metal products	3,91	5,26	8,76	8,43	14,37	13,86
Motor vehicles	-2,30	-2,36	-2,21	-2,19	-3,27	-3,27
Other trans. equipment	-1,24	-1,65	-1,96	-1,84	0,73	0,86
Electronic equipment	2,74	4,86	13,83	14,82	52,51	53,83
Other mach. and equip.	-10,96	-12,25	-9,59	-8,37	12,05	13,44
Other manufactures	20,00	29,43	52,84	53,50	79,46	80,36
Water	-0,02	-0,01	0,03	0,02	0,05	0,04
Construction	**-0,97**	**-1,74**	**-3,38**	**-3,28**	**-3,74**	**-3,62**
Services	**-0,90**	**1,68**	**12,37**	**13,15**	**29,42**	**30,14**
Trade	0,17	-1,70	-6,45	-5,39	-4,10	-2,79
Land transport	0,10	1,15	5,07	5,09	8,70	8,69
Sea transport	1,34	2,59	6,81	6,18	10,27	9,33
Air transport	0,89	2,98	9,17	8,91	14,12	13,73
Communication	-0,04	0,76	3,35	3,42	5,07	5,17
Financial services	-0,48	-0,57	-0,64	-0,57	-0,67	-0,58
Insurance	-0,64	-0,61	-0,33	-0,23	0,05	0,18
Business services	-0,62	-0,42	-0,27	-0,09	0,53	0,75
Recreation and other services	-1,23	-1,70	-2,74	-2,64	-2,86	-2,75
Public services	-0,41	-0,80	-1,60	-1,52	-1,69	-1,58
Dwellinbgs	0,00	0,00	0,00	0,00	0,00	0,00
Total	**24,08**	**28,17**	**34,16**	**30,40**	**238,27**	**231,03**

Now, we turn to the simulation results of the four scenarios. Without any further policy implication, BAU scenario shows China's economy will continue her economy growth rhythm. As shown in Table 7, real GDP will further grow another 42%, with a 20% increase of SO_2 emission as price. The Coal consumption intensity will be further reduced during economy growth. And this reduction will be compensated by the relatively faster increase in consumption of the other energy, especially as natural gas. However, the rigidity in the oil dependence seems difficult to resolve, since we can always find an almost 1:1 increase of oil consumption with respect to GDP growth continuously.

To achieve the 10% SO_2 reduction objective in 2005, we estimate an emission tax rate growth path to meet the needed policy strictness respectively for DESULFUR and LIB+DESULFUR scenario. For the simple DESULFUR scenario, we need the SO_2 emission tax rate to increase about 150% each year and finally to attain US$2.05 per Kilo of SO_2 in year 2005 (1997 US$).[14] And the corresponding tax rate need to be a little higher in the case where the de-sulfur policy is applied side by side with China's openness promise and the tax rate in year 2005 is US$2.23 per kilo of SO_2, given further open procedure will enlarge the economy scale. Since most of the SO_2 pollution reduction objective is achieved in industrial sectors, we will concentrate out attention in industrial sector's changes. Comparing to the original ad valorem wedges added to the energy price that we showed in Table 4 for benchmark year 1997, this time, the high emission tax will bring much more important ad valorem wedge to energy price. For example, the price wedge on coal caused by the emission tax in year 2005, in the case of Desulfur scenario will be about 104% and that for oil is about 7.4%. Clearly, this changes in the prices structure brought by emission tax is the key to encourage producer to change their energy composition and then to realize SO_2 emission reduction. Corresponding to the similar studies for Mexico and Argentine (Beghin et al., 1997, 1998), it seems the new de-sulfur objective will only induce quite slight foregone for Chinese economy (-0.93 fro DESULFUR scenario and only –0.18 for LIB-DESULFUR combined scenario). The main contribution to the pollution reduction comes from the general energy intensity reduction and energy composition transformation from coal-intensive to gas and electricity intensive. While relatively, industrial gross output and export will receive more loss than the average level of the total economy.

Contrary to the expectation of many optimist, further commercial liberalization seems to bring only modest economy (0.81) and income growth (2.13) effect with respect to the potential level that China can attain in BAU scenario. The most manifesting impact of trade liberalization is to enlarge the share of export and import in China's economy. Without a further policy to control SO_2 pollution, trade liberalization will cause SO_2 emission to increase further, even slightly faster than the proportional level vis-à-vis the real GDP growth (1.09% vs. 0.81%).

Under the coordination between trade and pollution control policy, the combined effect is almost additive in terms of all the economic indicators, such as GDP, gross output, trade and income growth, etc.(Table 7). Similar to Bighin et al. (1997, 1998), the magnitude of the necessary emission tax almost stays at the same level. While interestingly, the additive situation cannot be applied to energy consumption. Clearly, trade-desulfur policy combination seems further facilitate the substitution of coal by the other three less sulfur-polluting energies. We can see from Table 7 where the coal consumption reduction in combined scenario is slightly higher than the additive sum of the two scenarios of separate policy.

Tables 11-18 furnish more detailed information on the structure changes in the four policy scenarios. Without either policy, BAU scenario shows the most possible industrial structure transformation for China given her currently industrial policies. Clearly, as an industrializing country, the most important output increase in the future 5 years will happen in industrial sector. However, different from our expectation, excepts electronic equipment

[14] This is equal to 8.34 Yuans per Kg SO_2 according to PPP exchange rate: 1 US$=4.07691 RMB.

sector, it seems the most important expansion in production will not happen in her comparative advantaged labor-intensive sectors, but in some heavy industries as metal, machinery, motor vehicle, other transportation equipment, and chemical products sectors. That in fact reveals the fact that China's economy policy intention possesses "heavilization" inclination, which might be traced from her of the current production tax structure. While the high SO_2 emission tax in Desulfur scenario will actually impede this "heavilization" tendency since those heavy industries are generally the most polluting sectors. We find that beside the three energy sectors, coal, oil and electricity, whose output reduction can be explained by the direct demand reduction in intermediary consumption (-25.88% for coal, -7.44% for oil and –2.83% for electricity), resides correspondingly in those heavy industries (chemical products, -3.78%, ferrous metal, -2.95%, electricity, -2.83%, and other metal, -2.52%, Table 11, column DESULFUR). Commercial liberalization seems to further reinforce the transformation of industrial structure in this direction. Given China's tariff and export tax reduction promise, LIB simulation forecasts a even more significant reduction in some heavy industries which are equally capital-intensive sectors, as motor vehicle, -7.69%, ferrous metal, -3.57% and other metal, -3.93%. As supposed by international trade theory, the resources released from these disadvantage sectors will induce a even more rapid production expansion in some labor-intensive sectors, given the favorable trade condition under her WTO accession procedure, we anticipate a further 34.39% increase in wearing apparel sectors with respect to BAU scenario and another 5.36% growth for textile, 5.38% for electronic equipment and 4.05 for leather production. Totally speaking, owing to trade liberalization, the share of industrial production will increase by another 1.05% vis-à-vis BAU scenario, which make a contrast with the 1.37% reduction in the DESULFUR scenario. The Lib-Desulfur combination scenario seems further accelerates this "labor-intensive" sector deviation tendency in China's industrial composition change. Since the "labor-intensive" sectors in which China possesses comparative advantage are, generally less-polluting sectors, we can observe from the last column of Table 11, column LIB+DESULFUR, the further increase of output in textile, wearing apparel, leather production and electricity equipment sectors. Since most of the demand for heavy industrial products, as metal or chemical products can be more easily satisfied by import given tariff reduction, we observe equally, the further reduction tendency in those heavy industrial production. Globally speaking, since the output reduction in the polluting sectors is compensated by the increase in light export-orientated sectors, we will equally find a smaller industrial production reduction under the combination scenario comparing to the single de-sulfur policy scenario.

Comparing sectoral SO_2 emission distribution between different policy scenarios. We find that without trade policy's intervention, the pollution control objectively will make rather even SO_2 emission reduction in all the industrial sectors (-37%, Table 12, column DESULFUR). While in the presence of trade liberalization, we observe rather disproportional redistribution of SO_2 pollution between different sectors since the further open policy exerts in fact an industrial composition re-organization effect. By deducting the output changes in Table 11 from the corresponding SO_2 emission changes in Table 12 for the same sector, we van get some idea about SO_2 intensity changes in each sector. We find the 1% increase in SO_2 emission in LIB scenario with respect to BaU comes principally from the scale enlargement of Chinese economy under this new open procedure. However, under trade liberalization situation, this one percent's pollution increase is in fact the final result of complicated production structure and uneven sectoral pollution performance changes. Except some sectors show rather stable pollution performance and whose SO_2 variation is caused principally by the changes of production scale (majority of food sectors, paper and publishing, metal industry, etc.). We observe, interestingly, some curious pollution intensity increase case in some energy sectors (coal, oil and gas) and also, more extraordinary, in all the export-oriented sectors, which is reflected by a larger SO_2 emission increase than its output growth, especially for wearing apparel sector (50.84% of SO_2 increase vs. 34.39% of output growth). This situation might be explained by the fact that augmentation in (domestic or foreign) market demand can incur some reduction of the relative cost of pollution tax for producer, since they face higher market price for their product. However, given China's low SO_2 emission tax rate in the LIB scenario, the generally reduction of SO_2 emission in most of the heavy and SO_2-intensive pollution reflects in fact the absence of the "pollution haven" hypothesis. Currently, it seems that China's traditional comparative advantage in relatively cleaner labor-intensive sectors in fact dominates her environmental comparative advantage as a "pollution haven". Trade liberalization should not be considered to be an important environment deterioration factor. Furthermore, combination of trade and pollution reduction policy seems to be a good remedial measure for the SO_2 intensity increase situation mentioned a little above. A pollution control policy side-by-side of the open policy will, on one hand, permit Chinese economy to harvest the fruit of liberalization by exporting more to other countries, and on the other hand, impose a more exigent requirement on the pollution reduction performance on all the sectors, especially on the export-led sectors whose pollution performance risks to increase under liberalization. Correspondingly, we can see that with respect to LIB scenario, the significant pollution reduction achievement can be found in most export-intensive sectors (textile, -42.53%, wearing apparel, 56.19%, leather product, -37.18%, electronic equipment, 39.33%).[15]

Further analysis on the cause of SO_2 emission intensity reduction needs us to look into the detailed information on the energy consumption structure variation for each sector in different scenarios. Since we will go back to this point a little later with Divisia decomposition method. We only give rough description on the results about industrial energy consumption changes recorded in Table 13-16. Comparing the total SO_2 emission variation and that of coal consumption. In all the four scenarios and for almost all the industrial sectors, we can trace the same variation tendency for both indicators, and the slight positive gap between the SO_2 emission variation extent and that of the coal use in the majority of the sectors reveals the existence of substitution between coal with the other less polluting energies (oil, electricity) instead of no-polluting energy (gas). Several exceptions for this SO_2-coal common variation tendency are oil and petroleum, chemical product and three transportation and communication service sectors where the principal energy input are in fact oil but not coal. The substitution extent between coal and other energy inputs also well correspond to the actual SO_2 effluent rate of different energies. Generally we observe relatively larger increase in gas use than the other two types of energies in most of the sectors. What is the role of commercial liberalization in SO_2 emission changes? Without further policy to control SO_2 emission, LIB simulation recorded in Table 13-16 shows the variation in all the four energy input uses seem to follow very similar tendency as that for output changes. We can observe only slight but general higher increases (or lower reduction) of oil and electricity consumption than that of the other two energies, which is not at all sufficient to realize the obvious energy structure cleaning as that obtained under de-sulfur policy scenario. Therefore, although trade may, to some extent, offer producers more possibility to reduce their coal consumption by bring to domestic energy input market more supply of relatively cleaner energies, as imported oil, gas and electricity. Since the pollution reduction is not the principal preoccupation under liberalization scenario, the chained structural and scale changes in economy and energy consumption under liberalization will not automatically favorite the environment amelioration. Furthermore, corresponding to that we find from SO_2 intensity changes, for most export-oriented sectors and energy sectors, we find a out-proportional increase of their energy consumptions (e.g. the energy consumption increase in textile, wearing apparel, leather production, electronic equipments sectors are generally several points higher than their output increase, especially for wearing apparel sectors, the different attains almost 20 percent point. Table 11 vs. Table 13-16). Which in fact reveals the source of their SO_2 pollution.

[15] Here the comparation is done between the column LIB+DESULFUR and column LIB in Table 12.

Under the policy combined scenario, besides the additive energy changes from LIB and DESULFUR scenarios in most of the sectors, we observe another two important sources of forces that cause more energy structure changes. Firstly, the additive sum of the changes in electricity and gas changes from the separated LIB and DESULFUR scenarios are generally slightly lower than that we can find in LIB+DESULFUR combined scenarios. This shows trade liberalization in fact reduces the clean energy constraints in China by enlarging her energy import, especially that in electricity, oil and gas, which further facilitates her energy structure's de-sulfur procedure.[16] Secondly, besides the trade's clean energy supply role, it seems the export-oriented sectors, under the pressure of pollution control policy, will be able to realize even more significant energy structure de-sulfur change than the other ordinary sectors, this finding is especially obvious in the coal and oil consumptions changes, where the absolute additive variation is much lower than that indicated in the combined scenario results. This finding can be regarded as the concrete explication to the significant SO_2 intensity reduction observed in these sectors that discussed several paragraphs above.

One explanation for us to define electricity as less- instead of non-polluting energy as gas or the polluting energy as coal is the following. Electricity generation is in fact the most pollutant sector in China's economy since we use intensively coal combustion in electricity generation procedures (see Table 12 and 13). The transformation of energy use from coal to electricity in fact means a discharge of SO_2 pollution burden to the electricity generation sector. While comparing the variation tendency of electricity sector's output and its SO_2 emission shows that under pollution control policy, since 1997, this sector is always trying to reducing its SO2 emission intensity. Till 2000, it has succeeded in reducing its SO_2 intensity by (1.83-41.78)%=-40.95%, which is the most important source for total SO_2 emission reduction. And our simulation results in Desulfur and Lib+Desulfur scenarios also show that this source will continue to contribute to SO_2 reduction objective during 2000-2005 if the policy insists. Therefore, we can only define electricity as a less-polluting energy since its production stays still polluting though significant So_2 reduction achievement have been obtained.

The detailed trade variations for each scenario are shown in Table 17 and 18 and the related trade balance changes are shown in Table 19. As the results of energy composition changes under new pollution policy, net coal export will increase and contrary tendency can be found for the other three energies. Trade liberalization policy will generally facilitate import, which reflects as the general and important import increase in all sectors. While the most significant import increase appears in the LIB+DESULFUR scenario where the gas and electricity import will increase with astonishing percentage (52.89% for gas and 182.66% for electricity), which is even much higher than the additive sum from the two separated policy scenarios. While the export expansion seems relatively less spectacular than that of import, with the most important export increase performance recorded in textile, wearing apparel, vegetable oil and fat and electronic equipment sectors. The pollution control policy seems to have some "pollution haven" comparative advantage correction impact, since under the combined scenario, China's chemical products, rubber and plastics export will show significant reduction. Combining trade variations in different sectors, what will be their global influence on China's trade balance? From table 19, we see that although the de-sulfur policy will cause some reduction in the surplus of trade balance, this lose is proven to be quite small (less than 4 billions US$ in BaU scenario and a little more than 7 billion US$ under LIB scenario). Moreover, given the potential significant gain in foreign reserve from China's WTO accession policy, this little lose of surplus (about 3% of total potential gain) will in fact be totally compensated by the further gain from trade enlargement.

Since the central attention of this model is to see how trade can exerts its impact on environment, and how and through which channels its impact will change the cost of China's

[16] See table 17 and 18.

new desulfur policy. According to Grossman (1995), trade can exert its impact on SO_2 emission through the following channels. Firstly, trade can enlarge the production scale (scale effect), trade can change the industrial composition (composition effect) and trade can equally reinforce emission intensity reduction effect, which is generally called as technique effect. Furthermore, in our model specification, we tried to further distinguish the technique effect into the following three aspect: the general technology progress effect that is indicated as λ (technique), the trade externality effect which is indicated as AT and BT for export and import externality respectively (externality), and the further possibility to reduce SO_2 emission intensity which comes from the substitution between polluting and less- or non-polluting energies in production (substitution). So that from our production function (4), the emission determination function of sector *i* can be expressed as equation (6).

$$SO_{2\,it} = ?_{f} \left(\frac{f_f X_{f,i} ? \times AT \times BT}{X_i} \right) \times \left(\frac{X_i}{?_i X_i} \right) \times ?_i X_i = ?_f f_f x_{i,f} ?(AT \times BT) x_i x \qquad (6)$$

Where X_i means the production output in sector *i* and $X_{f,i}$ is the consumption of energy *f* in sector *i* and we use *X* to mean the aggregate output of economy. From equation (6), we have equation (7) to show how the change in SO_2 emission comes from the variation of its different determinants.

$$SO_{2\,it} / SO_{2,0} = \frac{x_{i,ft}}{x_{i,f,0}} \times \frac{?_0}{?_t} \times \frac{(AT \times BT)_0}{(AT \times BT)_t} \times \frac{x_{i,t}}{x_{i,0}} \times \frac{x_t}{x_0} = ?sub \times ?tech \times ?ext \times ?com \times ?sca \qquad (7)$$

Thus, based on the parametric Divisia decomposition method, we can decompose the determination function of SO_2 variation into its five determinants' variations (Scale, Composition, Externality, Technique and Substitution) and a residual term. The corresponding decomposition result for the four policy scenarios is recorded in table 20-23. [17]

The Table 20 recorded the potential contribution of the five determinants in SO_2 emission given the currently applied industrial policies. As we can see, the most important SO_2 increase forces comes from production scale expansion, in which the contribution from the single electricity generation sector occupies almost 50% of the total SO_2 increase. Furthermore, the composition effect seems to further exacerbate this pollution deterioration tendency, which can be traced from the important positive numbers listed in the chemical product, metal and other heavy industries. Come to the technical determinant for SO_2 intensity. In BaU scenario, the most important SO_2 reduction forces are the general technological progress, or the neutral technique progress averagely applied in all the sectors. The secondly important pollution reduction force comes from energy substitution, while in this scenario, almost 100% of pollution reduction realized in economy from energy substitution comes from electricity substitution, and the energy substitution effect in the other sectors are generally very limited. Furthermore, trade externality also shows only slight SO_2 reduction impact. Totally speaking, under BaU scenario, China's SO_2 pollution problem will further aggravate during 2001-2005, where the only contribution of SO_2 emission reduction comes from the pollution control measures applied in electricity sectors.

[17] The detailed method of Divisia decomposition can be offered upon request.

Table 20. Decomposition of change in SO_2 emission in BAU Scenario (reference: 1997, Divisia method)

Sector	Effect						Net emission change
	Scale	Composition	Externality	Technique	Substitution	Residuals	
Agriculture	**137,87**	**-93,43**	**-3,15**	**0,00**	**74,93**	**0,01**	**116,23**
Paddy rice	5,32	-3,18	-0,12	0,00	4,43	0,00	6,45
Wheat	1,56	-1,72	-0,04	0,00	0,74	0,00	0,54
Other cereal grains	4,53	-4,82	-0,10	0,00	2,22	0,00	1,83
Vegetables and fruits	30,73	-23,40	-0,70	0,00	20,22	0,01	26,86
Oil seeds	1,71	-2,11	-0,04	0,00	0,72	0,00	0,28
Sugar cane and beet	0,30	-0,26	-0,01	0,00	0,18	0,00	0,21
Plant-based fibers	5,57	-3,75	-0,13	0,00	3,48	0,00	5,17
Other crops	0,73	-0,95	-0,02	0,00	0,29	0,00	0,05
Bovine cattle	2,28	-1,22	-0,05	0,00	1,58	0,00	2,58
Other animal products	42,76	-31,86	-0,98	0,00	19,71	-0,01	29,63
Raw milk	0,17	-0,07	0,00	0,00	0,15	0,00	0,25
Wool, silk-worm cocoos	1,03	-0,93	-0,02	0,00	0,40	0,00	0,47
Forestry	11,90	-4,70	-0,27	0,00	5,04	0,00	11,96
Fishing	29,29	-14,46	-0,67	0,00	15,76	0,01	29,94
Manufacturing	**4573,18**	**917,08**	**-133,37**	**-2271,85**	**-929,61**	**-0,55**	**2154,88**
Coal	0,27	-0,18	-0,01	-0,13	0,03	0,00	-0,02
Oil	746,48	434,56	-17,04	-370,84	121,77	0,00	914,93
Gas	20,86	-0,90	-0,48	-10,36	-0,68	-0,01	8,44
Electricity	1941,51	-10,54	-44,33	-964,50	-922,35	-0,28	-0,49
Mining	28,02	7,06	-0,64	-13,92	3,59	-0,01	24,10
Bovine cattle, sheep	0,85	-1,72	-0,02	-0,42	-1,18	0,00	-2,49
Other meat products	0,91	-0,96	-0,02	-0,45	-0,32	0,00	-0,85
Vegetable oils and fats	10,08	-6,35	-0,23	-5,01	-8,28	0,00	-9,79
Dairy products	0,60	-0,49	-0,01	-0,30	-0,54	0,00	-0,74
Processed rice	27,05	-17,63	-0,62	-13,44	-14,92	0,00	-19,56
Sugar	0,13	-0,27	0,00	-0,06	-0,25	0,00	-0,46
Other food products	5,20	-4,56	-0,12	-2,58	-7,27	0,00	-9,33
Beverages and tobacco	27,81	-2,72	-0,29	-13,82	-10,12	0,00	0,87
Textiles	53,38	4,85	-1,80	-26,52	-12,27	-0,01	17,64
Wearing apparel	6,65	0,22	-0,22	-3,30	0,23	0,00	3,57
Leather products	2,74	-4,19	-0,06	-1,36	-0,59	0,00	-3,46
Wood	16,25	1,65	-0,48	-8,07	-0,84	0,00	8,51
Paper prod., publishing	49,83	1,82	-1,51	-24,76	-3,17	-0,01	22,20
Chem. Prod., rub. plast.	628,19	189,11	-25,39	-312,07	-46,84	-0,06	432,94
Other mineral products	446,19	127,34	-17,37	-221,66	0,33	-0,07	334,76
Ferrous metals	354,57	121,26	-14,27	-176,14	-12,64	-0,06	272,71
Other metal	43,70	18,60	-1,80	-21,71	-5,75	-0,01	33,02
Metal products	18,97	5,39	-0,74	-9,43	0,17	0,00	14,36
Motor vehicles	15,73	5,08	-0,68	-7,81	-2,16	0,00	10,16
Other trans. equipment	9,05	3,28	-0,37	-4,50	0,03	0,00	7,50
Electronic equipment	4,60	2,35	-0,20	-2,28	0,15	0,00	4,62
Other mach. and equip.	84,28	29,84	-3,45	-41,87	-0,11	-0,02	68,66
Other manufactures	27,80	14,63	-1,18	-13,81	-5,40	0,00	22,03
Water	1,48	0,57	-0,03	-0,74	-0,25	0,00	1,03
Construction	**23,46**	**6,21**	**-0,54**	**-11,65**	**8,04**	**0,00**	**25,51**
Services	**466,94**	**39,88**	**-10,66**	**-231,96**	**137,91**	**0,07**	**402,17**
Trade	71,38	6,36	-1,63	-35,46	24,48	0,02	65,16
Land transport	166,20	48,65	-3,79	-82,57	47,44	0,05	175,97
Sea transport	51,39	37,24	-1,17	-25,53	16,74	0,00	78,67
Air transport	28,79	21,36	-0,66	-14,30	7,16	0,00	42,35
Communication	3,61	1,66	-0,08	-1,79	-0,90	0,00	2,49
Financial services	4,16	1,15	-0,09	-2,07	0,75	0,00	3,90
Insurance	1,11	0,37	-0,03	-0,55	0,14	0,00	1,05
Business services	16,43	0,18	-0,38	-8,16	-1,16	0,00	6,91
Recreation and other services	12,70	0,99	-0,29	-6,31	3,11	0,00	10,20
Public services	111,11	-78,12	-2,54	-55,20	40,16	0,00	15,42
Dwellinbgs	0,06	0,05	0,00	-0,03	-0,01	0,00	0,07
Total	**5201,45**	**869,75**	**-147,71**	**-2515,47**	**-708,74**	**-0,48**	**2698,79**

Table 21. Decomposition of change in SO_2 emission in Desulfur scenario (reference: 1997, Divisia method)

Sector	Effect						Net emission change
	Scale	Composition	Externality	Technique	Substitution	Residuals	
Agriculture	**139,00**	**-93,37**	**-3,22**	**0,00**	**88,17**	**0,00**	**130,59**
Paddy rice	5,31	-3,15	-0,12	0,00	4,74	0,00	6,78
Wheat	1,56	-1,71	-0,04	0,00	0,84	0,00	0,65
Other cereal grains	4,53	-4,78	-0,10	0,00	2,48	0,00	2,13
Vegetables and fruits	30,72	-23,21	-0,71	0,00	22,14	0,00	28,93
Oil seeds	1,71	-2,10	-0,04	0,00	0,83	0,00	0,40
Sugar cane and beet	0,30	-0,26	-0,01	0,00	0,19	0,00	0,23
Plant-based fibers	5,58	-3,73	-0,13	0,00	3,88	0,00	5,59
Other crops	0,73	-0,95	-0,02	0,00	0,34	0,00	0,10
Bovine cattle	2,34	-1,23	-0,05	0,00	1,98	0,00	3,03
Other animal products	43,92	-32,33	-1,02	0,00	26,89	0,00	37,46
Raw milk	0,18	-0,07	0,00	0,00	0,18	0,00	0,28
Wool, silk-worm cocoos	1,05	-0,93	-0,02	0,00	0,55	0,00	0,65
Forestry	12,03	-4,77	-0,28	0,00	6,43	0,00	13,41
Fishing	29,05	-14,14	-0,67	0,00	16,71	0,00	30,95
Manufacturing	**3813,13**	**610,59**	**-108,33**	**-1925,10**	**-2819,56**	**-13,73**	**-443,01**
Coal	0,18	-0,22	0,00	-0,09	-0,15	0,00	-0,29
Oil	688,52	319,87	-15,93	-347,61	62,84	0,05	707,75
Gas	16,65	-0,12	-0,39	-8,41	-13,63	-0,14	-6,03
Electricity	1618,91	-68,71	-37,45	-817,33	-1710,35	-8,23	-1023,14
Mining	21,43	5,16	-0,50	-10,82	-15,67	-0,15	-0,54
Bovine cattle, sheep	0,72	-1,43	-0,02	-0,37	-1,61	0,00	-2,70
Other meat products	0,73	-0,76	-0,02	-0,37	-0,90	0,00	-1,32
Vegetable oils and fats	8,26	-5,27	-0,19	-4,17	-13,12	-0,04	-14,53
Dairy products	0,49	-0,39	-0,01	-0,25	-0,85	0,00	-1,02
Processed rice	21,65	-13,92	-0,50	-10,93	-30,61	-0,09	-34,40
Sugar	0,11	-0,23	0,00	-0,06	-0,30	0,00	-0,48
Other food products	4,26	-3,68	-0,10	-2,15	-9,68	-0,02	-11,37
Beverages and tobacco	21,88	-1,96	-0,25	-11,05	-26,68	-0,07	-18,13
Textiles	41,47	4,43	-1,43	-20,94	-46,09	-0,21	-22,77
Wearing apparel	5,20	0,37	-0,18	-2,63	-4,27	-0,04	-1,54
Leather products	2,26	-3,39	-0,05	-1,14	-2,31	-0,02	-4,65
Wood	12,63	1,49	-0,39	-6,38	-11,50	-0,07	-4,21
Paper prod., publishing	38,73	1,60	-1,20	-19,55	-35,69	-0,18	-16,29
Chem. Prod., rub. plast.	528,01	132,46	-19,74	-266,57	-301,91	0,27	72,53
Other mineral products	347,28	98,37	-13,19	-175,33	-283,28	-1,96	-28,09
Ferrous metals	274,73	84,68	-10,26	-138,70	-229,94	-1,70	-21,18
Other metal	34,02	13,66	-1,35	-17,18	-31,40	-0,27	-2,52
Metal products	14,59	4,12	-0,57	-7,37	-12,40	-0,11	-1,73
Motor vehicles	12,21	4,00	-0,53	-6,17	-11,90	-0,10	-2,48
Other trans. equipment	6,97	2,60	-0,29	-3,52	-5,94	-0,05	-0,22
Electronic equipment	3,62	1,96	-0,16	-1,83	-2,72	-0,03	0,85
Other mach. and equip.	64,91	23,65	-2,70	-32,77	-55,84	-0,46	-3,21
Other manufactures	21,40	11,75	-0,93	-10,81	-22,90	-0,13	-1,61
Water	1,28	0,47	-0,03	-0,65	-0,76	0,00	0,32
Construction	**19,31**	**5,29**	**-0,45**	**-9,75**	**-4,95**	**-0,05**	**9,40**
Services	**421,59**	**39,33**	**-9,75**	**-212,85**	**7,39**	**1,89**	**247,61**
Trade	64,86	6,55	-1,50	-32,75	4,59	0,55	42,30
Land transport	153,32	44,63	-3,55	-77,40	13,15	1,06	131,21
Sea transport	47,79	31,28	-1,11	-24,13	11,61	0,01	65,45
Air transport	27,27	20,18	-0,63	-13,77	4,32	0,01	37,37
Communication	3,45	1,63	-0,08	-1,74	-1,17	0,00	2,10
Financial services	3,73	1,07	-0,09	-1,88	-0,51	0,03	2,34
Insurance	0,99	0,35	-0,02	-0,50	-0,22	0,01	0,62
Business services	13,23	0,27	-0,31	-6,68	-10,55	-0,10	-4,13
Recreation and other services	10,52	0,91	-0,24	-5,31	-3,68	-0,03	2,16
Public services	96,39	-67,57	-2,23	-48,66	-10,10	0,35	-31,82
Dwellinbgs	0,05	0,04	0,00	-0,02	-0,05	0,00	0,01
Total	**4393,02**	**561,85**	**-121,75**	**-2147,69**	**-2728,95**	**-11,89**	**-55,41**

Table 22. Decomposition of change in SO_2 emission in LIB scenario (reference: 1997, Divisia method)

Sector	Effect						Net emission change
	Scale	Composition	Externality	Technique	Substitution	Residuals	
Agriculture	**138,89**	**-99,12**	**-3,44**	**0,00**	**77,94**	**0,01**	**114,28**
Paddy rice	5,27	-3,45	-0,13	0,00	4,28	0,00	5,98
Wheat	1,93	-1,36	-0,05	0,00	1,47	0,00	2,00
Other cereal grains	4,49	-5,12	-0,11	0,00	2,23	0,00	1,49
Vegetables and fruits	31,09	-24,42	-0,77	0,00	21,03	0,01	26,94
Oil seeds	1,48	-2,54	-0,04	0,00	0,50	0,00	-0,59
Sugar cane and beet	0,30	-0,28	-0,01	0,00	0,17	0,00	0,17
Plant-based fibers	5,73	-3,82	-0,14	0,00	3,81	0,00	5,58
Other crops	0,69	-1,04	-0,02	0,00	0,27	0,00	-0,09
Bovine cattle	2,31	-1,27	-0,06	0,00	1,64	0,00	2,63
Other animal products	43,16	-33,14	-1,07	0,00	20,38	-0,01	29,32
Raw milk	0,17	-0,08	0,00	0,00	0,15	0,00	0,25
Wool, silk-worm cocoos	1,02	-0,98	-0,03	0,00	0,38	0,00	0,39
Forestry	11,72	-5,93	-0,29	0,00	5,14	0,00	10,64
Fishing	29,53	-15,70	-0,73	0,00	16,47	0,01	29,58
Manufacturing	**4649,85**	**921,87**	**-143,10**	**-2284,72**	**-887,60**	**-0,62**	**2255,67**
Coal	0,27	-0,18	-0,01	-0,13	0,04	0,00	-0,01
Oil	763,43	451,48	-18,90	-375,11	132,97	0,00	953,87
Gas	21,38	-0,45	-0,53	-10,51	-0,31	-0,01	9,58
Electricity	1989,18	52,87	-49,25	-977,39	-920,49	-0,32	94,60
Mining	27,99	5,44	-0,69	-13,75	3,72	-0,01	22,69
Bovine cattle, sheep	0,84	-1,79	-0,02	-0,41	-1,14	0,00	-2,53
Other meat products	0,89	-1,07	-0,02	-0,44	-0,30	0,00	-0,94
Vegetable oils and fats	9,69	-7,82	-0,24	-4,76	-8,13	0,00	-11,26
Dairy products	0,59	-0,56	-0,01	-0,29	-0,53	0,00	-0,80
Processed rice	26,95	-19,43	-0,67	-13,24	-14,42	0,00	-20,81
Sugar	0,12	-0,30	0,00	-0,06	-0,23	0,00	-0,47
Other food products	4,88	-5,56	-0,12	-2,40	-7,04	0,00	-10,25
Beverages and tobacco	26,80	-7,18	0,21	-13,17	-10,49	0,00	-3,84
Textiles	56,46	9,78	-2,24	-27,74	-8,97	-0,01	27,28
Wearing apparel	8,40	4,66	-0,37	-4,13	2,13	0,00	10,69
Leather products	2,85	-4,13	-0,07	-1,40	-0,48	0,00	-3,24
Wood	16,37	0,97	-0,49	-8,04	-0,54	0,00	8,26
Paper prod., publishing	48,47	-5,04	-1,31	-23,82	-3,48	-0,01	14,81
Chem. Prod., rub. plast.	632,38	166,70	-26,55	-310,72	-39,99	-0,06	421,77
Other mineral products	453,54	121,35	-18,16	-222,85	10,96	-0,08	344,76
Ferrous metals	352,08	92,13	-14,62	-172,99	-10,13	-0,07	246,39
Other metal	43,21	14,59	-1,87	-21,23	-5,64	-0,01	29,04
Metal products	19,27	5,06	-0,79	-9,47	0,65	0,00	14,71
Motor vehicles	14,99	2,47	-0,70	-7,36	-2,86	0,00	6,52
Other trans. equipment	9,27	3,36	-0,40	-4,56	0,34	0,00	8,02
Electronic equipment	4,92	2,90	-0,23	-2,42	0,64	0,00	5,81
Other mach. and equip.	84,38	25,53	-3,67	-41,46	0,45	-0,02	65,21
Other manufactures	28,75	15,55	-1,32	-14,13	-4,11	-0,01	24,74
Water	1,51	0,56	-0,04	-0,74	-0,22	0,00	1,07
Construction	**24,27**	**6,92**	**-0,60**	**-11,92**	**9,27**	**-0,01**	**27,93**
Services	**476,27**	**35,17**	**-11,79**	**-234,02**	**154,38**	**0,07**	**420,09**
Trade	72,91	5,58	-1,81	-35,83	27,45	0,02	68,33
Land transport	168,58	44,83	-4,17	-82,83	51,87	0,05	178,32
Sea transport	52,88	38,85	-1,31	-25,98	18,55	0,00	82,99
Air transport	29,76	22,43	-0,74	-14,62	8,60	0,00	45,43
Communication	3,72	1,71	-0,09	-1,83	-0,74	0,00	2,77
Financial services	4,24	1,09	-0,10	-2,08	0,89	0,00	4,03
Insurance	1,13	0,35	-0,03	-0,55	0,16	0,00	1,05
Business services	16,70	-0,11	-0,41	-8,21	-0,71	-0,01	7,26
Recreation and other services	12,99	0,95	-0,32	-6,38	3,60	0,00	10,83
Public services	113,30	-80,54	-2,81	-55,67	44,71	0,00	19,00
Dwellinbgs	0,06	0,05	0,00	-0,03	-0,01	0,00	0,07
Total	**5289,28**	**864,85**	**-158,93**	**-2530,66**	**-646,01**	**-0,54**	**2817,98**

Table 23. Decomposition of change in SO_2 emission in LIB+DESULFUR scenario
(reference: 1997, Divisia method)

Sector	Effect						Net emission change
	Scale	Composition	Externality	Technique	Substitution	Residuals	
Agriculture	**140,15**	**-99,22**	**-3,52**	**0,00**	**91,83**	**0,00**	**129,24**
Paddy rice	5,26	-3,42	-0,13	0,00	4,61	0,00	6,32
Wheat	1,93	-1,34	-0,05	0,00	1,61	0,00	2,15
Other cereal grains	4,50	-5,08	-0,11	0,00	2,50	0,00	1,81
Vegetables and fruits	31,09	-24,27	-0,78	0,00	23,08	0,00	29,12
Oil seeds	1,49	-2,53	-0,04	0,00	0,60	0,00	-0,48
Sugar cane and beet	0,29	-0,28	-0,01	0,00	0,19	0,00	0,19
Plant-based fibers	5,74	-3,80	-0,14	0,00	4,24	0,00	6,04
Other crops	0,70	-1,04	-0,02	0,00	0,31	0,00	-0,04
Bovine cattle	2,38	-1,28	-0,06	0,00	2,06	0,00	3,10
Other animal products	44,39	-33,68	-1,11	0,00	27,86	0,00	37,44
Raw milk	0,18	-0,08	0,00	0,00	0,19	0,00	0,28
Wool, silk-worm cocoos	1,04	-0,99	-0,03	0,00	0,54	0,00	0,56
Forestry	11,86	-6,03	-0,30	0,00	6,56	0,00	12,09
Fishing	29,29	-15,39	-0,74	0,00	17,48	0,00	30,65
Manufacturing	**3850,77**	**595,08**	**-115,78**	**-1923,47**	**-2844,52**	**-15,38**	**-453,30**
Coal	0,18	-0,22	0,00	-0,09	-0,15	0,00	-0,29
Oil	700,43	325,80	-17,58	-349,87	68,74	0,05	727,58
Gas	16,90	0,20	-0,42	-8,44	-13,86	-0,16	-5,78
Electricity	1647,41	-18,97	-41,34	-822,89	-1741,59	-9,35	-986,73
Mining	21,22	3,81	-0,53	-10,60	-15,85	-0,16	-2,12
Bovine cattle, sheep	0,71	-1,49	-0,02	-0,36	-1,58	0,00	-2,74
Other meat products	0,71	-0,85	-0,02	-0,36	-0,88	0,00	-1,39
Vegetable oils and fats	7,91	-6,48	-0,20	-3,95	-12,87	-0,04	-15,63
Dairy products	0,47	-0,44	-0,01	-0,24	-0,84	0,00	-1,06
Processed rice	21,45	-15,26	-0,54	-10,71	-30,41	-0,10	-35,57
Sugar	0,10	-0,25	0,00	-0,05	-0,29	0,00	-0,49
Other food products	4,00	-4,51	-0,10	-2,00	-9,36	-0,02	-11,99
Beverages and tobacco	21,01	-5,47	0,14	-10,49	-26,65	-0,07	-21,54
Textiles	43,34	8,29	-1,75	-21,65	-45,97	-0,25	-17,99
Wearing apparel	6,43	3,88	-0,29	-3,21	-3,94	-0,05	2,82
Leather products	2,33	-3,30	-0,06	-1,16	-2,32	-0,02	-4,53
Wood	12,62	0,96	-0,39	-6,31	-11,52	-0,08	-4,71
Paper prod., publishing	37,46	-3,83	-1,03	-18,71	-35,63	-0,19	-21,94
Chem. Prod., rub. plast.	527,71	107,54	-20,54	-263,59	-301,35	0,40	50,17
Other mineral products	349,72	92,24	-13,68	-174,69	-284,13	-2,20	-32,74
Ferrous metals	270,38	59,49	-10,45	-135,06	-229,84	-1,86	-47,33
Other metal	33,38	10,24	-1,39	-16,67	-31,38	-0,29	-6,13
Metal products	14,68	3,82	-0,61	-7,33	-12,40	-0,12	-1,97
Motor vehicles	11,59	1,91	-0,54	-5,79	-12,14	-0,10	-5,08
Other trans. equipment	7,08	2,64	-0,31	-3,54	-5,93	-0,06	-0,11
Electronic equipment	3,83	2,39	-0,18	-1,91	-2,56	-0,04	1,52
Other mach. and equip.	64,49	20,15	-2,85	-32,21	-56,32	-0,51	-7,25
Other manufactures	21,91	12,36	-1,03	-10,94	-22,76	-0,14	-0,60
Water	1,30	0,46	-0,03	-0,65	-0,75	0,01	0,34
Construction	**19,84**	**5,87**	**-0,50**	**-9,91**	**-4,51**	**-0,05**	**10,74**
Services	**428,54**	**34,58**	**-10,75**	**-214,05**	**17,48**	**2,12**	**257,91**
Trade	66,07	5,83	-1,66	-33,00	6,54	0,61	44,40
Land transport	155,07	40,74	-3,89	-77,46	16,01	1,17	131,64
Sea transport	48,96	32,31	-1,23	-24,45	12,92	0,01	68,51
Air transport	28,12	21,11	-0,71	-14,05	5,48	0,01	39,96
Communication	3,55	1,69	-0,09	-1,78	-1,02	0,00	2,35
Financial services	3,78	1,01	-0,09	-1,89	-0,43	0,04	2,42
Insurance	1,00	0,33	-0,03	-0,50	-0,20	0,01	0,61
Business services	13,35	0,05	-0,34	-6,67	-10,47	-0,11	-4,19
Recreation and other services	10,70	0,87	-0,27	-5,34	-3,51	-0,03	2,41
Public services	97,88	-69,39	-2,46	-48,89	-7,78	0,41	-30,22
Dwellinbgs	0,05	0,04	0,00	-0,02	-0,05	0,00	0,01
Total	**4439,30**	**536,31**	**-130,55**	**-2147,43**	**-2739,73**	**-13,31**	**-55,41**

Comparing Table 20 and 21 can give us some synthetic idea about the possible channel through which the new de-sulfur policy will exert its impact. Implement of the de-sulfur policy will absolutely reduce the potential SO_2 emission increase owing to expansion of production scale. The pollution augmentation comes from composition changes will also become less than BaU scenario with the most important reduction in the most polluting sectors as electricity generation and other heavy industries. Since the total production scale reduces, thee amelioration effect from trade externality and general technological progress reduce proportionally. Corresponding to our previous discussion, we find the most important factor that permits China to attain her pollution reduction objective resides in energy substitution effect. And under the pollution control policy, the important SO_2 emission results caused by this effect seems to be wide-spread in the economy and can be observed in all the sectors from Table 21.

Following, we compare Table 20 with Table 22 to see what is the environmental impact of trade liberalization if China executes only her WTO accession promises. With respect to BaU scenario, trade liberalization will only bring modest supplementary pollution increase due to production scale expansion. While, contrary to our expectation, industrial composition changes under commercial liberalization do not bring significant contribution to SO_2 reduction. A careful study on the detailed SO_2 emission variations for each sector shows that, although there exists some expansion in labor-intensive sectors the industrial composition under trade liberalization. These sectors, as textile, wearing apparel and electronic equipment do not realize significant pollution reduction given their production scale growth in industrial composition. At the same time, we do not neither observe very clear pollution share reduction tendency in most of the heavy industries. Furthermore, since the pollution reduction achievement from energy substitution effect also seems to reduce with respect to that in BaU scenario. Though some increase in pollution reduction contribution from trade's externality and from the general technical progress channel are found, totally speaking, for the case of China, trade liberalization will result in a relatively modest "increase" in SO_2 pollution. This is due to, generally speaking, two facts. First is her pro-heavy industrial policies that favorite the existence and expansion of these polluting sectors and that revealed in her production tax structure, and the second is the curious increase of polluting energy use in the export and energy sectors' production given their higher demand price over-weighting the unchanged pollution tax cost for producer

Finally, to understand how trade liberalization will not make the new de-sulfur policy become too much more expensive for China's economy, we compare the Table 22 and 23. Clearly, with the presence of international trade, the reduction of SO_2 emission due to production scale changes become less important than the case where only pollution control policy is implemented. This is due to the fact that, given China's comparative advantage stay always in some labor-intensive sectors that is relatively less polluting sector, the necessity to shrink production scale due to pollution reduction requirement can be now relaxed to some extent by a more important industrial composition transformation toward less-polluting one. Furthermore, trade externality and general technique progress will also have a little more pollution reduction effect as the production scale does not reduce so much as that in Desulfur scenario. At the same time, the co-existence of trade and pollution control policy seems facilitate the realization of a more efficient energy substitution effect. Correspondingly, we find in table 23 the SO_2 emission reduction coming from energy substitution effect is also slightly higher than that we find in Table 22. This is can be explained by the fact that trade liberalization in fact offers China more possibility to satisfy her increased clean energy demand (especially as gas and electricity demand) by importing instead of producing them domestically, which avoids the SO_2 emission from their production process. Given the three environment-friendly channels from the technique aspect and the composition changes under trade liberalization, we find that in the policy combined scenario, the contribution in total SO_2

emission reduction that comes from the heavy and polluting industries will further increase with respect of that in de-sulfur scenario. Clearly, the combination of the trade and pollution control policies seems to be more efficient in terms of pollution reduction, especially for the case of SO_2 emission, since they offer Chinese economy more channels to adapt her economy growth, structure transformation with her pollution control objective.

Before concluding, one interesting point need to mention is that although Divisia index decomposition method seems to be quite efficient as the residual terms are generally quite small, we equally find these terms have the tendency to increase once the de-sulfur policy is imposed. This reflect the possibility that there exists, besides the five determinants mentioned in this paper, other potential explanation factors, which can be a very interesting topic for the further deepening of this analysis.

6. Conclusion

In this paper, with aid of a CGE model, we tried to understand the actual role of trade in China's environment deterioration. Given China's WTO accession permission and her de-sulfur policies that will be implemented simultaneously during 2001 to 2005, this offer us a perfect policy situation to analyze the possible trade-pollution nexus in China.

The specification of this model offers us the possibility to analyze multiple aspects of this complicated trade-pollution nexus. On one hand, as most CGE models, we suppose trade can exert impact on SO_2 pollution by Enlarging production scales and encouraging industrial structure to be more specialized according to her comparative advantage characters. On the other hand, we also make a trade-externality specification in the model, which can capture the potential production efficiency gains related directly to trade liberalization. Furthermore, by attributing to the substitution possibility to energy intermediary consumption, we get one further channel that permits us to trace the possible contribution of trade in pollution reduction – facilitating the energy substitution by change the supply-demand structure through the trade enlargement. Therefore, by this model, we have a much more detailed analysis mechanism that will help us to understand in more details about how these different channel will work together to change the future SO_2 emission situation in China, given her actual structural characteristics and her current industrial policy. In addition, this model will also permit us to measure the efficiency of the currently applied pollution levy system in China and to find the necessary emission tax rate increase path to meet the newly implemented quite ambitious de-sulfur policy.

With helps of this model, and using the most complete and current SAM that available for us, in this paper we would like to get a more detailed and more realistic understanding on whether trade will facilitate or impede the execution of the new pollution policy and how it can do that. By answering these question, we will have a better understanding on the nexus between trade and pollution, furthermore, to be able to give more realistic policy suggestion on China's new pollution policy application and to create, if possible, a better coordination between this two important policies for China's economy and environment, for China's today and more important, for China's future.

Our result shows that the environmental impact of trade on China's economy, though proven to be negative, will stays rather small, this finding corresponds to many other researches studying the similar problems though we do not share the same analysis method. The advantage of this CGE model offered us a chance to understand with more details about how this relatively small negative impact comes into being. Clearly, trade will cause China's economy to expand. However, given China's rich labor endowment, her natural comparative advantage in labor-intensive industries seems to dominate her comparative advantage to be a "pollution haven". The new de-sulfur policy will further reinforce this domination situation and the total SO_2 emission increase caused by economy scale enlargement under trade liberalization will be cancelled off to some extent by the obvious cleaning tendency in China's composition transformation. At the same time, although not very important in volume, the factor efficiency amelioration effect brought by the trade externality will also contribute supplementary SO_2 emission reduction with trade scale expansion. Furthermore, trade liberalization can also relax the traditional self-dependence exigency in energy supply in China, which is previously satisfied by her own production. Under trade liberalization, the increase in demand of the clean energy, especially that of electricity and gas can thereafter satisfied by import, which will absolutely offer China more chances to reduce her SO_2 pollution quantity. Although the environment-friendly impacts of trade in the above three aspects does not seem to be large enough to reduce all the increase of pollution caused by economy scale enlargement, the co-ordination between them only leave us a relatively small total negative impact in environment. Correspondingly, the extra cost of pollution reduction caused by the presence of trade liberalization also seems to be relatively limited. We even proved that the combination of the two policy seems to be a good choice to reduce the possible economic choc that would be brought by a singly de-sulfur policy, since the reduction in real GDP in LIB+DESULFUR scenario (-0.18) will be remarkably slower than that for the DESULFUR scenario (-0.91).

Our analysis also shows that the currently applied levy rate on SO_2 emission is too low for the newly implemented ambitious de-sulfur objective. A much strict emission tax rate evolution path should be applied if China wants to encourage producers to adopt some pollution reduction measures in their profit-maximization decision. We find this tax rate should be increase by 150% each year and to attains about 2.23 US$ per kilo of SO_2 in year 2005.

Come to the policy implication. Firstly, trade should not be considered as a pollution deterioration factor, especially for the case of China. However, the detailed results also call our attention to be paid to the possible pollution increase in labor-intensive sectors under liberalization. Since their higher demand price will, in turn reduce the relative cost of pollution tax to their producers. This curious finding in fact remind Chinese environment administration to place some supplementary policy instrument to discourage this source of pollution increase, such as a emission tax rate a little higher, or a pollution reduction quota a little more exigent than that we can find from simulation results. Furthermore, from sectoral level, China should pays more attention to her most pollutant sectors—electricity generation, since over 50% of the SO_2 pollution comes from this sector. A better transformation in her energy input composition (such as to increase the ratio of nuclear electricity generator) would bring even remarkable pollution reduction results.

At last, as our analysis is founded on an optimal policy choice base, the distribution of the reduction ratio in each sector is in fact determined by the model itself. These ratios can also be served as a guideline for the distribution of pollution reduction quota. Furthermore, given China's further industrial policies, this distribution design can also be used as a base to guide government in using the distribution of pollution reduction quota between sectors to interfere the structure evolution of the economy.

Reference

Anderson, D. and W. Cavendish (2001), Dynamic Simulation and Environmental Policy Analysis: Beyond Comparative Statics and the Environmental Kuznets Curve, *Oxford Economic Papers*, vol. 53, pp721-746.

Ang, B.W. and G. Pandiyan (1997), Decomposition of energy-induced CO_2 emissions in manufacturing, *Energy Economics*, Vol. 19, pp363-374.

Antweiler, W., B. R. Copeland and M.S. Taylor (2001), "Is Free Trade Good for The Environment?", *American Economic Review*, Vol. 91, No.4, Sept, pp 877-908.

Beghin, J., B. Bowland, S. Déssus, D. Roland-Holst, (1999), Trade, Environment, and Public Health in Chile: Evidence from an Economy-wide Model, in P.G. Fredriksson eds. *Trade, Global Policy, and the Environment*, World Bank, 1999, pp35-54.

Beghin, J., S. Dessus, D. Roland-Holst and D. van der Mensbrugghe (1996), *General Equilibrium Modelling of Trade and the Environment*, Technical paper, No. 116, OECD.

Beghin, J., S. Dessus, D. Roland-Holst and D. van der Mensbrugghe (2002), Trade Integration, Environmental Degradation, and Public Health in Chile: Assessing the Linkage, Environment and Development Economics, Vol. 7, Part 2, pp241-267.

Beghin, J., S. Dessus, D. Roland-Holst and D. van der Mensbrugghe (1997), The Trade and Environment Nexus in Mexican Agriculture: A Genral Equilibrium Analysis, *Agricultural Economics*, Vol. 17, pp115-131.

Beijing Environment, Science and Technology update, 14, June, 2002. The base the emission level of year 2000.

Cao, D., J. Yang and C. Ge (1999), SO_2 Charge and Taxation Policies in China: Experiment and Reform, in (OECD eds.) *Environmental Taxes: Recent Developments in China dn OECD Countries*, OECD, 1999, pp233-257.

Copeland, B. and M. S. Taylor (1997), *A Simple Model of Trade, Capital Mobility and the Environment*, NBER, No. 5898.

Copeland, B. and M. S. Taylor, (1994), "North-South Trade and the Environment", *The Quarterly Journal of Economics*, August, 1994, pp755-787.

De Melo, J., and S. Robinson (1990), *Productivity and Externalities: Models of Export-led Growth*, Mémo. 90.10, University of Geneva.

Dessus, S. and M. Bussolo (1998), Is There a Trade-off Between Trade Liberalization and Pollution Abatement? A Computable General Equilibrium Assessment Applied to Costa Rica, *Journal of Policy Modeling*, Vol. 20(1), pp.11-31.

Dessus, S., D. Roland-Holst and D. van der Mensbrugghe (1994), *Input-based Pollution Esimates for Environmental Assessment in Developing Countries*, Technical papers, No. 101, OECD.

Grossman, G. (1995), "Pollution and growth: What do we know?", Goldin and Winter (eds.), *The Economics of Sustainable Development*, Cambridge University Press, 1995.

Hettige, H., R. E. B. Lucas and D. Wheeler (1992), "The Toxic Intensity of Industrial Production: Global Patterns, Trends, and Trade Policy", *American Economic Review*, Vol. 82, No. 2, pp478-481.

Kemfert, C., (1998), Estimated Substitution Elasticities of a Nested CES production funcion approch for Germany, *Energy Economics*, Vol. 20(1998), pp249-264.

Kemfert, C., and H. Welsch, (2000), Energy-Capital-Labor Substituion and the Economic Effects of CO_2 Abatement: Evidence from Germany, *Journal of Policy Modeling*, Vol. 22(6), pp641-660.

Lawrence Berkeley National Laborarory (2001), *China Energy Databook, v.5.0*, Berkeley, 2001.

Lee, H. and D. Roland-Holst (1997), The Environment and Welfare Implications of Trade and Tax Policy, *Journal of Development Economics*, Vol. 52, pp.65-82.

Lucas, R. E., B.D. Wheeler, and H. Hettige (1992), "Economic Development, Environmental Regulation and the International Migration of Toxic Industrial pollution : 1960-1988", P. Low (Ed), *International Trade and the Environment*, Banque Mondiale, Discussion paper No. 159, Washington, DC.

Pethig, R. (1976), "Pollution, Welfare, and Environmental Policy in the Theory of Comparative Advantage", Journal of Environmental Economics and Management, Vol. 2, pp160-169.

Qiang, J. and K. Zhang (1998), China's Desulfurization Potential, *Energy Policy*, Vol. 26, No. 4, pp345-351.

Rock, M. T., (1996), "Pollution Intensity of GDP and Trade Policy: Can the World Bank Be Wrong?", *World Development*, Vol. 24, No. 3, pp. 471-479.

Rogrigo, G. C., and E. Thorbecke, (1997), Sources of Growth: A Reconsideration and General Equilibrium Application to Indonesia, *World Development*, Vol. 25, No. 10, pp1609-1625.

Roland-Holst, D. and D. Van der Mensbrugghe (2002), *Prototype Specification for a Real Computable General Equilibrium Model of China*, Date of current version: Oct. 21, 2002.

SEPA, (1998-2000), *China's Environmental Statisitic Yearbook*, Beijing.

Shen, L. (1997), *Speech make at the Clean Coal Initiative Conference*, World Bank.

Tobey, J. A. (1990), The effect of domestic environmental policies on patterns of world trade: An empirical test, *Kyklos* 43 (2), 191-209.

Van der Mensbrugghe, D., D. Roland-Holst, S. Dessus, and J. Beghin (1998), The Interface Between Growth, Trade, Pollution and Natural Resource Use in Chile: Evidence from an Economywide Model, Agricultrual Economics, Vol. 19, pp 87-97.

Wang, Z. (2002), The Impact of China's WTO accession on Patterns of World Trade, *Journal of Policy Modeling*, Vol. 5298, pp1-42.

World Bank (1996), China : *Chongqing Industry pollution control and reform project,* Staff Appraisal Report, Washington DC.

Xu, X., B. L. Li, et H. Y. Huang(1996) , *Air Pollution and Unscheduled Hospital outpatient and Emergency Room Visits*. Environmental Health Prospective.

Xu, X., J. Gao, D. W. Dockery et Y. Chen (1994), *Air Pollution and Dailu Mortality in Residential Area of Beijing*, China. Archives of Environmental Health, 49(4), pp216-222.

Yang, H-Y, (2001), Trade Liberalisation and Pollution: A General Equilibrium Analysis of Carbon Dioxide Emissions in Taiwan, *Economic Modelling*, Vol. 18, pp435-454.

Yang, J. and S. Benkovic (2002), The Feasibility of Using Cap and Trade to Achieve Sulfur Dioxide Reductions in China, *The Sinosphere Journal*, Vol. 4, Issue 1, July, 2002, pp10-14.