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Climate Change Strategy and Sustainable Power Technologies in China

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Abstract

Global warming will be a large common issue human beings face in the 21st century. In general, the phenomenon of global warming is almost proportionally related with the pace of industrialization, which has to be resolved with high priority. In this research, a policy mix as a kind of climate change strategy is proposed, imposing carbon tax in China. Based on available data, an eco-conscious socioeconomic framework model is built and several scenarios of energy use and CO_2 emission are developed in order to evaluate comprehensively the effect of carbon tax on CO_2 emission curtailment and introduce suitable alternative energy in China. Sustainable power technologies mean solar power technology and wind power technology in the research.

Keywords: CO_2, China, climate change, environmental modeling, sustainable power technologies

JEL classification: D81; O11; Q25; Q43

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1 Introduction

Global warming will be a large common issue human beings face in the 21st century. At the Third Conference of Parties to the United Nations Framework Convention on Climate Change (COP3) held in Kyoto, it was agreed by 161 participating nations to do their best in the period from 2008 to 2012 to curtail global warming gases as per the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). Generally, carbon dioxide (CO_2) makes the largest contribution to the global warming among greenhouse gases (GHGs; Figure 1-1). This gas is released into the environment mostly by combustion of fossil fuel for energy use. Among the fossil fuels, coal is the fuel that discharges most CO_2 when burned. Because the carbon content per calorific value of coal is on average 30% higher than that of oil, the coal is a major cause for the increase in the amount of CO_2 discharged, especially with China where the energy dependence on coal was 66.1% in 2000 (China National Bureau of Statistic (NBS), 2003). Therefore, from the viewpoint of taking measures against global warming, it is desirable not only to aim at achieving efficient energy consumption but also to shift from coal to other energy sources, which discharge lesser amounts of CO_2 than coal, such as nuclear power or other forms of alternative energy.

China is a developing country. Generally speaking, in a developing country, if policies for improving energy efficiency are adopted in order to reduce the air pollution, it implies that policies for CO_2-reduction have been adopted simultaneously.

The source of energy has been diversified and the competition among energy sources has become severe. For instance, the demand for the natural gas known as ‘clean energy’ has been expanded rapidly since 1997 in China. It is considered that the natural gas will play an important role at least in the process for de-carbonization, namely the process of decreasing the amount of CO_2 discharged per unit usage of energy. However, direct regulations of the energy supply and demand have been dominant so far in China and any market-oriented environmental policy has not yet been adopted in order to reduce the total emissions of CO_2. The energy problem and environmental problem in the new century will become more serious with the rapid economic growth in China, and the policy measures against global warming taken by the central government, such a policy mix imposing carbon tax as a kind of climate change strategy need to be considered and evaluated.

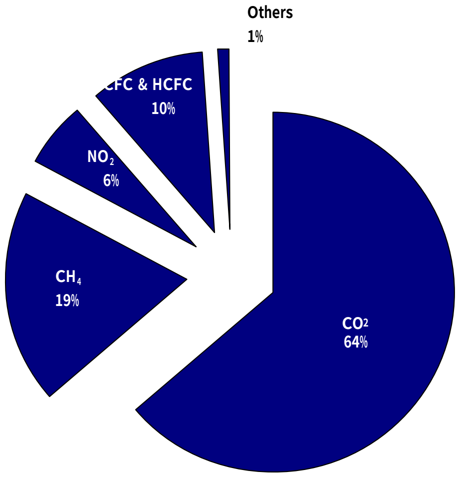

Figure 1-1 Contribution to global warming of each greenhouse gas from the Industrial Revolution to 1992
Source: Intergovernmental Panel for Climate Change (IPCC), 1996a.

This paper consists of five Chapters. We introduce the purpose briefly in Chapter 1, the state of the energy sector and CO_2 levels in China in Chapter 2, our model in Chapter 3, the simulation results in Chapter 4 and finally the conclusion are described in Chapter 5.

2 Background

Global warming is closely related with both global environmental issues and global energy issues. And there are many countermeasures against global warming that should be taken from various aspects. In this research nation-wide environmental tax and advancement of alternative energy are focused on.

2.1 CO_2 Emissions in China

The government of China recognizes the seriousness of the problems and China is now a signatory to several international conventions including the Convention for the Protection of the Ozone Layer, and the Convention on Biological Diversity. China was one of the first countries in the world to devise an Agenda 21 after the Rio conference on the environment in 1992 paving a way towards environmental sustainability in the 21st century. And on September, 2003, China ratified the Kyoto Protocol. Although China has been able to de-couple its energy use from GDP growth, the continuous economic and population growth will inevitably increase future energy consumption requirements. Since 1999 China has been the second largest country in the emissions of CO_2 (Figure 2-1). Furthermore, according to a report by the World Health Organization (WHO), China has become one of the most polluted countries and she occupies seven among the most polluted ten cities in the world (IEA/OECD, 2002). Environmental pollution affects the agriculture and forestry production. Actually, it is estimated that the direct cost of environmental damage due to the pollution in the 1990s has been amounted to 7% of the GDP in China (Sinton and Fridley, 2000). Environmental pollution also caused ill-health. For example, two conditions such as chronic obstructive pulmonary disease and lower respiratory tract infections, linked to air pollution, they accounted for 1.9 million annual deaths for all ages, namely over 21% of all deaths in China. (*Source*: http://www.who.int/world-health-day/2003/infomaterials/Brochure2/en/).

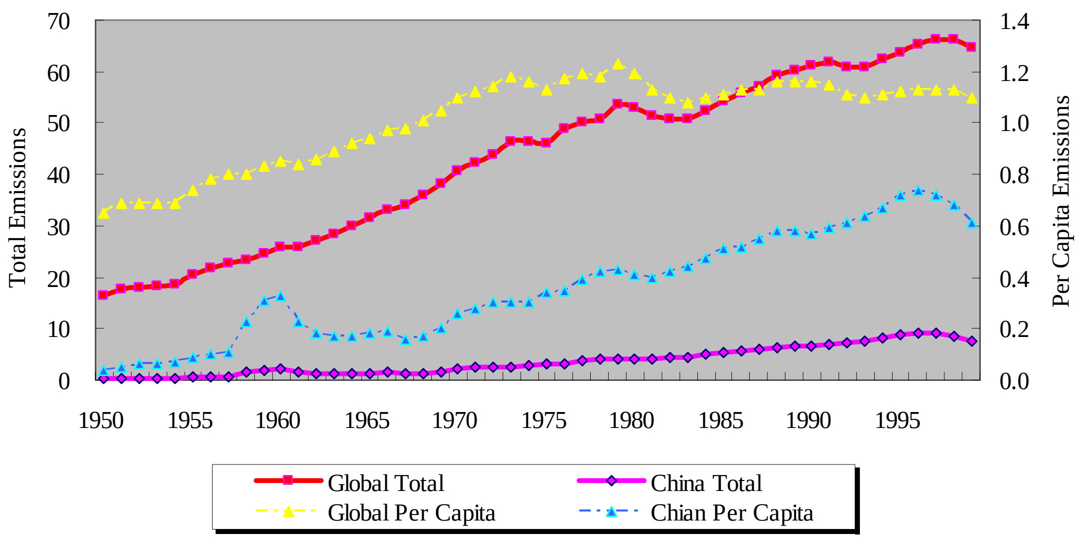

Figure 2-1 Global and China fossil fuel CO_2 emissions, 1950-2001
(Units: 100 million tons carbon, ton carbon/per capita)
Source: http://cdiac.esd.ornl.gov/ftp/trends/emissions/prc.dat,
http://library.iea.org/dbtw-wpd/Textbase/nppdf/free/2003/key2003.pdf

2.2 Environmental Taxes

Taxes and permit trading systems are seen as effective means of helping to achieve environmental objectives and to implement important sustainability principles such as 'the polluter pays'. They can complement regulation and specific agreements to address complex challenges such as climate change, which require changes in behavior across the economy. Economic instruments can be more effective than regulation in both environmental and economic terms. And they fit an underlying tax philosophy which argues that there should be a shift from levies on desirable activities ('goods') to undesirable ones ('bads').

Many countries have introduced environmental taxes over the past decade, covering a wide range of environmental targets. When fuel and vehicle duties are included, the OECD estimates that environmental taxes accounted for 7% of all tax revenues in 2000. The government aims to achieve inclusive social progress, environmental protection and prudent resource use, as well as high and stable levels of economic growth and employment to get to the triple objectives of social, economic and environmental sustainability. In the international context sustainable development also includes tackling poverty and disease in the developing world and narrowing the gap between rich and poor.

The tax system offers many options for reducing uncertainty and better allocating environmental costs. In its broadest sense, 'environmental tax reform' means lowering taxes on payroll, capital formation and clean energy technology, and financing those reductions with higher taxes on activities that hurt the environment. In addition, a portion of the revenues from environmental tax reform can be used to provide: transition for energy-intensive companies; assistance to low-income households; incentives for business to achieve energy efficiency and develop cleaner technologies and processes. Properly-designed environmental tax reform would offset any new costs to consumers and could be beneficial to low and moderate income peoples. Revenue from environmental taxes would lower other taxes and fund rebates and tax credits. Conservation programs, alternative energy sources, and clean technologies would help reduce consumption, further lowering energy costs.

There is solid proof that environmental tax reform and other market-based initiatives work. At the national level, taxes on ozone-depleting chemicals have reduced environmental destruction and provided a boost to clean technologies. States are increasingly adopting environmental tax initiatives, and nine European nations have changed their tax policies with measurable environmental and economic benefits. Market-based solutions like environmental tax reform are catching on because they appeal to diverse audiences. Environmentalists like its impact. Conservatives applaud its emphasis on tax simplicity. Business leaders respect its adherence to market principles. Reformers believe it is good government in action. And taxpayers support the tax relief it would provide.

3 Eco-conscious Socioeconomic Framework Model

3.1 Structure of the Model

The assumptions of the model include: in Chinese economy, there is an excessive amount of labor to substitute for capital; tradeable emission quotas are allocated by the government or other organization commissioned by the government under an emission trading system in a quasi-market; there exist 36 commodity markets, 36 capital markets and 33 consumption markets, and they are in equilibrium as of 1997; when the carbon tax is introduced, the markets remain equilibrium; emission coefficients do not change in the short term; industrial processes, waste disposals, fixation of CO_2 due to the change of forest and land use are not taken into consideration; carbon leakage is also not taken into consideration.

Carbon leakage refers to the indirect impacts of climate change policy, specifically the displacement of emissions from one source to another source. Under the Kyoto Protocol, the displacement of emissions between Annex I nations is captured through simulation to be the total cap of developed nations. However, this issue becomes problematic when the displacement is made between Annex I and non-Annex I nations, say CO_2 spill over into effects spill over into non-Annex I nations.

The model consists of the equations of 13 groups.

3.2 Sectoral Classification

Using the usual classification of 32 sectors, the sector of Electric Power, Gas and

Heat Supply is divided into sector of Electric Power and sector of Gas and Heat Supply. Adding two Alternative Energy sectors of Solar Power and Wind Power and one sector of Pollution Abatement, which removes CO_2 with cleaner technology such as methane fermentation, totally 36 sectors are supposed to exist in the economy of China (Table 3-1).

Table 3-1 Sectoral classification

Index	Sector	Index	Sector
1	Agriculture	19	Water
2	Mining	20	Whole sale and retail service
3	Food products	21	Finance and insurance
4	Textiles and clothing	22	Real estate services
5	Paper and wooden products	23	Transport
6	Chemical products	24	Communications
7	Coal and petroleum products	25	Public works
8	Non-metallic mineral products	26	Education and research services
9	Iron and steel	27	Medical, health and social insurance services
10	Non-ferrous metals	28	Other public services
11	Fabricated metal products	29	Miscellaneous business services
12	General machinery	30	Miscellaneous personal services
13	Electric machinery	31	Office supplies
14	Transport equipment, automobiles	32	Not elsewhere classified
15	Precision apparatus	33	Electricity
16	Other manufactures	34	Solar power
17	Building and construction	35	Wind power
18	Gas	36	Pollution abatement

The input coefficients of Solar Power sector and Wind Power sector were estimated using the I-O structure of the Household Electric Appliances sector and Generators sector, respectively. In addition, considering the social cost of CO_2 discussed so far in the world, the Pollution Abatement sector was estimated using the I-O structure of General Machinery sector. The cost of Abatement sector was estimated at 100 CNY/t in the research. The abatement industry is a virtual one. More realistically, we consider that if the process of waste treatment is changed into the one in which less CH_4 and nitrous oxide (N_2O) are emitted into the air, such change means a considerable amount of CO_2 emissions is reduced since one unit of CH_4 and N_2O is equivalent to 21 and 310 times of that of CO_2 respectively in the global warming effects once they are emitted into the air.

3.3 Framework of the Multi-sectoral Model including I-O Table

The model consists of the following equations of 13 groups including commodity flow balance on the usual sectors, commodity flow balance on the CO_2 pollution abatement sector, value flow balance on each sector, energy supply-and-demand restrictions, disposable income of household, investment and saving, consumption and saving level of household, production function, tax revenue, government expenditure, dynamic equation of capital stock, total emission standards of CO_2 pollution and finally objective function. One prominent feature of the model is the simultaneous decision on both commodity flow and value balance.

Since Walras's Law has come into effect, the price of the commodity of each sector in market equilibrium is just expressed as relative price. Therefore, in the model the sector of commodity of the not elsewhere classified sector (No.32) in the 1st term is set to be the numeraire of the integrated system, that is to say, P32(1) = 1. P32(2) is calculated endogenously according to the model. Other main parameters and basis for calculation are listed in Table 3-2.

Table 3-2 The main parameters used in the model

Parameter	Symbol	Value
Term	*Time*	2
The adjustment factor	θ	0.500
The average direct tax rate	τ^{a}	0.026
Depreciation rate of the government	δ^{g}	0.048
Savings propensity of the government	φ^{b}	0.351
Proportion of savings in disposable income	β^{c}	0.334
Social depreciation rate	ρ	0.050

Note: Basis for calculation

a, ***c***: Disposable income=Compensation of employees + Operating surplus

τ = (Disposable income - (Total household consumption + Private domestic gross fixed capital formation)) /(Disposable income)

β = 1 - ((Total household consumption) / ((1 - τ) * Disposable income))

b: φ = (Annual government revenue - Government current expenditure) / (Annual government revenue)

4 Scenarios Design, Simulation Results and Discussion

4.1 Scenarios Design

Hereafter, the simulation exercise of this research is explained.

In the simulation, the pollutant of artificial CO_2 which is the main GHG resulted from energy use is focused on. The software *LINGO of LINDO Systems* for mathematical programming to perform the simulation is used.

According to 'the 10th Five-Year (2001-2005) State Plan' of China, the regulation of the total pollutant emissions is tightened up successively, the solution of structural pollution will be improved, and the discharge of the total industrial pollutant in 2005 will be scaled down for 10% or more compared with that in 2000. Moreover, considering the restriction on the available data, the dynamic simulation based on the data in 1997 for three years (1997~1999 as the first term and 2000~2002 as the second term) is run. Cases are set in order to clarify the proper CO_2-reduction as followings.

Basic Case (baseline case): the CO_2 emissions and economic trend in China were estimated by the simulation using the built model calibrated on the I-O table of 1997. Here, neither CO_2 pollution abatement sector nor the carbon tax was considered. An emission restriction was not imposed.

Case-0 and Case-10 (reference case): supposing the existence of alternative energy sectors, the policy mean of a carbon tax was made and the emission restrictions of CO_2 were also set. In the last term, 0% and 10% of upper constraint on the emissions of CO_2 was performed as compared with the amounts of emissions in the Basic Case. The simulation of two cases of Case-0 (0% mitigation) and Case-10 (10% mitigation) were performed.

4.2 Simulation Result: Impact of Carbon Tax Introduction

4.2.1 Optimum Carbon Tax Rate

An optimum carbon tax rate required in order to attain the mitigation target is derived as 85.25 CNY/t-CO_2 (Table 4-1).

According to the present 'Resource Tax Enactment in People's Republic of China', the optimal carbon tax rate is nearly as much as 3 and 17 times of the resource taxes on crude oil and coal, respectively. This indicates that the inadequate pricing of natural resources and energy causes inefficient use and damage. At this stage it is impossible to apply carbon tax policy just because the carbon tax rate is optimal. This also means that it is quite difficult to establish the country-wide environmental taxation system in China which is one of developing countries.

Table 4-1 Optimum carbon tax rate, impact on public welfare by case and electricity generated by alternative energy sectors

Case	The optimum carbon tax rate	GNP (0.1 billion CNY)		Solar power (10,000 kWh)		Wind power (10,000 kWh)	
	($CNY/t\text{-}CO_2$)	1st term	2nd term	1st term	2nd term	1st term	2nd term
Basic Case	0	75,704	102,398	0.45	0.60	16.5	27.0
Case-0	85.25	75,246	103,418	0.50	0.65	23.6	46.7
Case-10	100.00	74,867	104,419	0.52	0.86	36.2	75.3

4.2.2 Impact on the Economy

The impact on the economic welfare is shown in the above (Table 4-1). GNP in the 1st term for Case-0 shows a slight decrease of 0.6% compared with the GNP in 1997 base year. It could be concluded that the level of production in this term as compared to the achievements in 1997 was scarcely maintainable due to introduction of the carbon tax. This is because of the delay in being effective effects by the alternative energy sectors and CO_2 pollution abatement sector which were just set up. This has resulted in the difference between the result of the simulation and the achievements in 1997 for CO_2 emissions or the production of Electricity sector. In the 2nd term, GNP in Case-10 exceeded the achievements in 1997 base and grew about 1.0% more than that in Case-0. Minimizing the short-term negative impact by the introduction of a carbon tax, the combination of the policy means of the carbon tax and a concrete mitigation target could make Chinese economy grow more rapidly.

Next, the impact on the sector is evaluated. Table 4-2 shows the change of products in each sector. In the 1st term of Case-0, the winners by the carbon tax introduction are Food Products (No.3), Transport Equipment and Automobiles (No.14), Transport (No.23), and Water (No.19), and the production level increases about 10.0%, 9.9%, 9.8% and 9.4% respectively. The sector with big damage is Public Works (No.25), General Machinery (No.12), Non-metallic Mineral Products (No.8) division, and the rate of declining production level are about 1.6%, 2.7% and 4.6%, respectively. In the

1st term of Case-10, the winners by the policy mix with a carbon tax introduction and 10% mitigation are Food Products (No.3), Medical, Health and Social Insurance Services (No.27), Transport Equipment and Automobiles (No.14), Transport (No.23), and Water (No.19), and production level increases about 10.0%, 10.0%, 9.9%, 9.8% and 7.4%, respectively. Worst-hit sectors are Mining (No.2), Electricity (No.33), Gas (No.18), General Machinery (No.12), and Public Works (No.25), product decreases 18.2%, 11.0%, 11.0%, 10.0% and 9.5% respectively. This also shows change of source of energy use. On the other hand, from the 1st term to the 2nd term of Case-0, winners are the Miscellaneous Personal Services (No.30), Real Estate Services (No.22), Finance and Insurance (No.21), Food Products (No.3), Coal and Petroleum Products (No.7), and Whole Sale and Retail Service (No.20), and the production level increases 29.4%, 29.4%, 29.4%, 20.9%, 19.4% and 19.1%, respectively. Worst-hit sectors are Public Works (No.25), Education and Research Services (No.26), Non-ferrous Metals (No.10), and Mining (No.2), and production level decreases 26.6%, 22.6%, 13.0% and 8.3%, respectively. Winners are the Miscellaneous Personal Services (No.30), Real Estate Services (No.22), Finance and Insurance (No.21), Whole Sale and Retail Service (No.20), and Food Products (No.3), and from the 1st term to the 2nd term of Case-10 production level increases about 29.4%, 29.4%, 29.4%, 19.1% and 17.6%, respectively. Worst-hit sectors are Mining (No.2), Public Works (No.25), Education and Research Services (No.26), and Non-ferrous Metals (No.10), and production level decreases about 28.7%, 22.6%, 20.6% and 18.1%, respectively.

Table 4-2 Change of products by sector, in 10 thousand CNY

Industry	Basic Case	Case-0		Case-10	
NO.		1st term	2nd term	1st term	2nd term
1	250,373,327	250,373,327	250,489,294	250,373,327	235,085,904
2	68,283,887	68,283,887	62,629,902	55,880,548	39,855,379
3	137,925,948	151,718,558	183,414,077	151,718,558	178,431,721
4	131,451,437	131,451,437	151,048,147	131,451,437	151,048,147
5	46,787,245	46,522,346	50,778,057	46,197,844	48,685,532
6	110,069,221	110,069,221	119,022,723	110,069,221	118,162,452
7	30,981,911	30,952,310	36,971,637	29,962,384	32,220,191
8	88,074,034	86,633,232	93,208,108	85,823,206	88,255,864
9	54,067,064	53,506,716	52,683,595	54,175,862	50,764,996
10	23,683,242	24,186,982	21,039,063	23,516,977	19,255,452
11	49,832,738	49,316,292	52,983,748	49,088,059	51,802,146
12	82,266,501	80,082,016	78,296,959	74,045,882	68,921,750
13	104,564,055	104,564,074	108,747,575	104,564,074	108,101,446
14	53,138,393	58,415,482	56,627,595	58,415,482	56,627,595
15	5,773,251	5,773,251	6,215,866	5,773,251	6,215,866
16	107,159,365	107,159,365	120,957,574	107,159,365	118,264,094
17	173,855,000	173,855,000	183,633,281	172,904,521	182,384,057
18	2,745,749	2,769,478	3,111,198	2,442,452	2,535,390
19	9,169,614	10,027,649	10,480,637	9,845,504	9,614,949
20	110,485,707	110,485,707	131,604,864	110,485,707	131,604,864
21	35,952,759	35,952,759	46,516,014	35,952,759	46,516,014
22	18,553,568	18,553,568	24,004,786	18,553,568	24,004,786
23	50,662,699	55,625,923	64,309,940	55,625,923	57,339,326
24	19,589,200	19,589,200	21,652,501	19,589,200	22,212,504
25	49,751,546	47,461,508	34,826,086	45,019,284	34,826,086
26	25,783,142	26,405,303	20,445,477	25,747,531	20,445,477
27	17,977,638	19,775,402	19,775,402	19,775,402	19,775,402
28	18,112,972	18,112,972	17,496,872	18,112,972	17,496,872
29	7,193,965	7,193,965	8,026,824	7,138,874	7,813,933
30	50,102,387	50,102,387	64,822,946	50,102,387	64,822,946
31	2,529,125	2,560,493	2,826,991	2,549,080	2,782,365
32	23,808,482	24,026,779	23,125,157	23,892,999	22,417,609
33	37,736,318	38,062,439	42,758,878	33,567,939	34,845,241

4.3 Discussion

Table 4-3 shows briefly various carbon tax rates in the world. It is made from various sources (Japan Ministry of the Environment (ME), 2004; IPCC, 1996b, etc.). Assumed that 1 JPY = 0.0662 CNY and 1 US$ = 8.2898 CNY as of 1997 and the average emission coefficient of electricity equals 0.38 kg-CO_2/kWh (NBS, 2003; ME, 2004), the carbon tax rate derived in Case-0 means 10 US$/t-$CO_2$ and 0.49 JPY/kWh. Through comparison among various carbon tax rates in the world, it is the lowest carbon tax rate.

Table 4-3 Various carbon tax rates in the world

Country	A carbon tax (US$/t-$CO_2$)	A carbon tax on electricity (JPY/kWh)	Initiated year
Finland	392	0.95	1990
Sweden	785	0	1991
Norway	667	0	1991
Denmark	539	1.77	1992
Britain	389	0.85	2001
Switzerland	726	0	2005 (scheduled)
Germany	348	2.69	1999
France	840	0	Illegal judgment in 2000
Netherlands	326	8.59	1988 or 1996
Italy	818	0	1999
Japan	73	0.25	2005 (scheduled)
U.S.	293	0	
Canada	191	0	

Source: ME, 2004; IPCC, 1996b, etc.

Several European countries have moved to implement pollution taxes within the framework of ecological or ‘green tax reform’, which seeks a systematic shift of the tax burden away from labor and/or capital and toward the use of environmental resources. As of 1997, environmental taxes in Sweden, Denmark, and Finland were part of a framework green tax reform (ME, 2004). As of 1999, six OECD nations levied carbon taxes: Denmark, Finland, Italy, the Netherlands, Norway, and Sweden. Finland’s carbon tax, the world’s first, was introduced in 1990. Italy’s carbon tax is a revenue-generating mechanism, part of a broad-ranging attempt to use indirect taxation to compensate for weaknesses in the direct taxation system. Carbon taxes in Denmark, Norway, and Sweden are intended to have an incentive effect, in addition to a revenue generating effect, but it has been difficult to determine the actual impacts of these policies. However, Swedish carbon taxes are relatively high and some impacts are evident. Claims have been made that the Swedish and Norwegian taxes have reduced carbon emissions, but in all the Nordic countries, except Finland, a variety of tax exemptions have made effective carbon tax rates significantly lower than nominal rates, thereby increasing skepticism regarding the efficacy of these policies. For example, Sweden's manufacturing tax exemptions and reductions result in effective CO_2 tax rates ranging from 19 to 44% of nominal rates. Danish industry has obtained tax relief on process energy, and power stations are exempt from coal taxes. Norway taxes only 60% of domestic CO_2 emissions, when exemptions and reductions are taken into account. Initiated in January 1991, Sweden's carbon tax grew out of a drastic reform of the national tax system that essentially consisted of cutting income taxes and energy taxes and raising or initiating value added taxes, sales taxes, and carbon taxes to offset the lost revenue. Although energy taxes were halved, the imposition of new carbon taxes more than compensated for this reduction. However, the 1991 tax regime was shortlived. Extensive lobbying by industry led to a second round of tax reforms in 1993 which differentiated taxes across sectors. The net effect of these reforms was to reduce energy prices relative to the 1991 level for industry, and to raise energy prices relative to the 1991 level for other sectors. A third round of tax reforms in 1997 doubled carbon taxes paid by industry. Revenue from carbon taxes is not earmarked. The administration of carbon taxes has been handled by existing tax authorities. It is difficult to evaluate the impact of the carbon tax on emissions since the imposition of the tax coincided with other fiscal reforms and since the tax has changed so frequently. Nevertheless, carbon taxes have significantly reduced emissions in some non-industrial sectors such as district residential heating. Revenue from carbon taxes has been substantial. In 1995, it generated 1.6 billion US$, approximately 1% of Sweden's GDP. Administrative costs attributed to carbon taxes are estimated at roughly 5% of total revenue.

The impact on the economic welfare and on sector is evaluated. However, considering that the CO_2 emission coefficient is estimated according to the Japan's data, some sector's result may not reflect the real state in China.

According to the simulation result, introduction of a carbon tax could promote growth of the alternative energy sectors. Further, with the mixture of the policy instruments of not only a carbon tax but also CO_2 specific mitigation target, growth of the alternative energy sectors can be accelerated.

In order to achieve the more emission mitigation of an air contamination substance, such as CO_2 while maintaining the growth of a certain scale economy, CT technical advance bringing the abatement expense down could be indispensable.

CO_2 mitigation potential for the sector of Mining (No.2), Iron and steel (No.9) and Transport (No.23) is conspicuous and need give enough attention.

As future issues, there are two points to improve the model.

Firstly, nuclear power generation was incorporated into the existing electricity sector in this research. In the foreseeable future, it is difficult to assume another option except nuclear power as non-fossil energy-giving source in China which is a developing country. Moreover, nuclear power utility is significant to establish and operate an artificial carbon management policy. Therefore, one of the future issues is to carry out the simulation by separating nuclear power generation from fired power generation.

Secondly, because China's CO_2 emissions, SO_2 pollution and acid rain come from coal combustion, it will be useful to integrate the existing environment policy for reducing SO_2 pollution with carbon tax introduction policy. The former policy focuses more attention in the local level while the later is more related with global environmental policy.

5 Conclusions

In this research, a policy mix as a kind of climate change strategy is proposed, imposing carbon tax in China. The results obtained by means of the policy simulation model for sustainable power technologies are summarized and conclusions could be given as follows.

The China's economy has been in the high-growth period since the late 1990s due to 'Chinese-type' stepwise economic reforms. Especially among the four aspects of basic necessities of life, namely 'clothing', 'diet', 'housing' and 'traveling', China achieved the former two aspects of 'clothing' and 'diet' with amazing growth rate. This implies that China has been able to de-couple the energy use from the high GDP growth rate because meeting the development of 'clothing' and 'diet' needs less energy. However, with increasing wealth, more and more peoples are seeking a higher standard of living, mainly on the latter two aspects of 'housing' and 'traveling'. Increased consumption leads to demand for more energy, and so to more demand for industrial products. It also leads to more waste including CO_2 emissions. Being fully committed to the regulations of World Trade Organization (WTO), it would be difficult for China to attain the emission mitigation target through energy-saving measures only.

The impact of introducing the carbon tax on energy-intensive sectors is serious. Energy-intensive sectors include such sectors as that of Electricity, Gas, Water, Mining, General Machinery and Non-ferrous Metals. Therefore, when considering introducing a carbon tax, preferential tax system for energy-intensive sectors might be sought. Introduction of the carbon tax could promote growth of the sustainable power technologies (solar and wind power). Moreover, with the mixture of the policy instruments of not only a carbon tax but also CO_2 specific mitigation target such as emission permits, the growth of the sustainable power technologies can be accelerated. Therefore, it could be expected that introducing the carbon tax being combined with appropriate policies becomes power to implement the measure in China.

Through comparison among various carbon tax rates calculated and discussed in developed countries, it turned out that the optimal carbon tax rate is the lowest in the world while a carbon tax on electricity is not so low. However, the optimal carbon tax rate is nearly as much as 3 and 17 times of the current resource taxes on crude oil and coal, respectively in China. Therefore, as one of the strategies for global warming, it is expected that it would be quite difficult to establish the country-wide environmental taxation system in China in the near future.

References

Agnolucci, P. and Ekins, P., 2004. The Announcement Effect and Environmental Taxation. Tyndall Centre for Climate Change Research Working Paper 53, 1-24 pp. Via Internet: *http://www.tyndall.ac.uk/publications/working_papers/wp53.pdf*, Read on 4, November 2004.

Amano, A., 1997. *Economics of Global Warming*. Nihon Keizai Shimbun Press, Tokyo, Japan, 228 pp. (in Japanese).

Amano, A., 2003a. *Research on Environmental Economics: For the Integration of Environment and the Economy*. Yuhikaku Press, Tokyo, Japan, 266 pp. (in

Japanese).

Amano, A., 2003b. *Perspective on Environmental Problems*. Kwansei Gakuin University Press, Kobe, Japan, 197 pp. (in Japanese).

Argent, R.M. and Grayson, R.B., 2003. A Modelling Shell for Participatory Assessment and Management of Natural Resources. *Environmental Modelling & Software*, 18(6), 541-551.

Brown, L.R., Flavin, C. and French, H., 2000. *State of the World: A Worldwatch Institute Report on Progress Toward a Sustainable Society*. W.W. Norton & Company, New York, USA, 422 pp.

Bye, B., 2002. Taxation, Unemployment, and Growth: Dynamic Welfare Effects of 'Green' Policies. *Journal of Environmental Economics and Management*, 43(1), 1-19.

Chae, Y. and Hope, C., 2003. Integrated Assessment of CO_2 and SO_2 Policies in North East Asia. *Climate Policy*, 3(1) Supplement, S57-S79.

Chen, Z.L., 1999. Studies on the Energy Demand/Supply in China's Economy. *A Doctoral Dissertation Presented to the Graduate School of Environment and Life Engineering*, *Toyohashi University of Technology*, Japan, 171 pp. (in Japanese).

China Renewable Energy Power Generation and Heat Use Research Item Group of State Economic and Trade Commission, 1999. *China Renewable Energy Technical Evaluation*. China Environmental Science Press, Beijing, China, 78 pp. (in Chinese).

China National Bureau of Statistic (NBS), 1996. *China Energy Statistical Yearbook*. China Statistics Press, Beijing, China, 478 pp. (in Chinese).

China National Bureau of Statistic (NBS), 1999a. *China Energy Statistical Yearbook*. China Statistics Press, Beijing, China, 554 pp. (in Chinese).

China National Bureau of Statistic (NBS), 1999b. *China Statistical Yearbook 1999*. China Statistics Press, Beijing, China, 909 pp. (in Chinese).

China National Bureau of Statistic (NBS), 1999c. *Input-Output Table of China 1997*. China Statistics Press, Beijing, China, 480 pp. (in Chinese).

China National Bureau of Statistic (NBS), 2003. *China Statistical Yearbook 2003*. China Statistics Press, Beijing, China, 977 pp. (in Chinese).

China State Development Planning Commission (SDPC), 2000. *China Alternative Energy and Renewable Energy 1999 White Paper*. China Planning Press, Beijing, China, 161 pp. (in Chinese).

Edit Committee of China Farm Village Energy Yearbook, 1997. *China Farm Village Energy Yearbook*. China Agriculture Press, Beijing, China, 137 pp. (in Chinese).

Encyclopedia Britannica, 2004. Alternative Energy. Via Internet: *http://www.britannica.com*, Read on 16, October 2004.

Energy Information Administration (EIA), China Country Analysis Briefs. Via Internet: *http://www.eia.doe.gov/emeu/cabs/china.html*, Read on 30, April 2003.

Forestry Planning Research Group, 1987. *Long-term Vision of New Forestry: Long-range Outlook for the Forestry Product Supply and Demand Based on Conversions of the Forest Maintenance Policy and a Supply-and-demand Equilibrium Model*. Chikyu-Sha Press, Tokyo, Japan, 415 pp. (in Japanese).

Fujita, K., 2001. *Research of Ecological Tax Reform: Expense Burden in Environment Policies*. Minerva Shobo Press, Tokyo, Japan, 209 pp. (in Japanese).

Fujita, M. and Krugman, P., 2003. The New Economic Geography: Past, Present and the Future. *Papers in Regional Science*, 83(1), 139-164.

Gao, G.L., 2003. Regional Redistribution: Western Region Development in China. Discussion Paper Read at *the 18th Pacific Conference of the Regional Science Association International* (PRSCO), Acapulco, Mexico, July, CD-ROM.

Gielen, D. and Moriguchi, Y., 2002. Modelling CO_2 Policies for the Japanese Iron and Steel Industry. *Environmental Modelling & Software*, 17(5), 481-495.

Hannon, B., 2001. Ecological Pricing and Economic Efficiency. *Ecological Economics*, 36(1), 19-30.

Hashimoto, K., 2003. *Introduction to Finance*. Zeimukeiri Kyokai Co., LTD., Tokyo, Japan, 309 pp. (in Japanese).

Hayano, T. and Tutiya, H., 1990. Modelling the Cost of Alternative Energy and Simulation. *Energy and Resource*, 11(2), 142-149. (in Japanese).

Hideyuki, I., Junnitiro, T., Masaaki, T. and Kuniaki, M., 2000. Hazard estimation of possible pyroclastic flow disasters using numerical simulation related to the 1994 activity at Merapi Volcano. *Journal of Volcanology and Geothermal Research*, 100, 503-516.

Higano, Y., 1996. Distribution of the Value Added to the Input of the Environmental Goods based on the Materials Balance Principle. *Studies in Regional Science*, 26(1), 181-187. (in Japanese).

Higano, Y., 1997. Optimal Taxes on the Emission of Air Pollutants in Japan. Discussion Paper Read at Session in Honor of Professor Hirotada Kohno: Environmental Policy and Sustainability of *the 15^th^ Pacific Regional Science Conference*, December, Wellington.

Honma, T., 1980. *Wind Power Reader*. Ohm Press, Tokyo, Japan, 236 pp. (in Japanese).

Ianchovichina, E. and Walmsley, T, 2003. The Impact of China's WTO Accession on East Asia. World Bank Policy Research Working Paper 3109, 1-28 pp. Via Internet: *http://econ.worldbank.org/files/28992_wps3109.pdf*, Read on 15, November 2004.

Ikeda, S., Sakai, Y. and Tawada, M., 2004. *Risk, Environment and Economy*. Keiso-Shobo Press, Tokyo, Japan, 234 pp. (in Japanese).

Intergovernmental Panel for Climate Change (IPCC), 1996a. *Climate Change 1995: The Science of Climate Change*. (Eds.) Houghton, J.T., et al., IPCC, WG I, Cambridge University Press, Cambridge, UK, 584 pp.

Intergovernmental Panel for Climate Change (IPCC), 1996b. *Climate Change 1995: Economic and Social Dimensions of Climate Change*. (Eds.) James, P. B., et al., IPCC, WG III, Cambridge University Press, Cambridge, UK, 458 pp.

Intergovernmental Panel for Climate Change (IPCC), 2001a. *Climate Change 2001: Impacts, Adaptation, and Vulnerability*. (Eds.) McCarthy, J., et al., IPCC, WG II, Cambridge University Press, Cambridge, UK, 1042 pp.

Intergovernmental Panel for Climate Change (IPCC), 2001b. *Climate Change 2001: Mitigation*. (Eds.) Metz B., et al., IPCC, WG III, Cambridge University Press, Cambridge, UK, 702 pp.

Intergovernmental Panel for Climate Change (IPCC), 2002. *Climate Change 2001: Synthesis Report*. (Eds.) Watson, R.T., IPCC, Cambridge University Press, Cambridge, UK, 408 pp.

International Energy Agency (IEA) and Organization for Economic Co-operation and Development (OECD), 1999. *World Energy Outlook: Looking at Energy Subsidies: Getting the Prices Right*. OECD, Paris, 224 pp.

International Energy Agency (IEA) and Organization for Economic Co-operation and Development (OECD), 2000. *World Energy Outlook*. OECD, Paris, 457 pp.

International Energy Agency (IEA) and Organization for Economic Co-operation and Development (OECD), 2001. *World Energy Outlook: Insights: Assessing Today's Supplies to Fuel Tomorrow's Growth*. OECD, Paris, 421 pp.

International Energy Agency (IEA) and Organization for Economic Co-operation and

Development (OECD), 2004. *World Energy Outlook 2004*. OECD, Paris, 576 pp.

Isard, W., 2003. *History of Regional Science and the Regional Science Association International: The Beginnings and Early History*. Springer-Verlag: Berlin-Heidelberg-New York, 267 pp.

Ishikura, T., Tansei, K. and Sugimura, Y., 2003. *Analysis of Nationwide Economic Impacts by Airport Development: Computable General Equilibrium Model Approach (Series: No.96, Technical Note of National Institute for Land and Infrastructure Management)*. National Institute for Land and Infrastructure Management, Tsukuba, Ibaraki, Japan, 13 pp. (in Japanese).

Jiyu Kokumin-Sha, 2002. *Basic Knowledge of Contemporary Term*. Jiyu Kokumin-Sha Press, Tokyo, Japan, 524 pp. (in Japanese).

Jorgenson, D.W., 1998. *Econometric General Equilibrium Modeling*. MIT Press, Cambridge, Massachusetts, USA, 448 pp.

Kashima, S., Hayes, W.J., Yamauti, K., Tanisita, M. and Hasuike, K., et al., 2003. *Automobile-tax System in the Century of Global Environment*. Keiso-Shobo Press, Tokyo, Japan, 189 pp. (in Japanese).

Kojima, T., 1998. *The Carbon Dioxide Problem: Integrated Energy and Environmental Policies for the 21st Century*. Translated from the Japanese edition, (Eds.) Harrison, B., Gordon and Breach Science, Amsterdam, the Netherlands, 226 pp.

Kratena, K., 2004. 'Ecological Value Added' in An Integrated Ecosystem–economy Model: An Indicator for Sustainability. *Ecological Economics*, 48(2), 189-200.

Leontief, W.W., 1951. *The Structure of American Economy, 1919-1939: An Empirical Application of Equilibrium Analysis (2nd Edition)*. Oxford University Press, New York, USA, 264 pp.

Li, B. and Higano, Y., 2000. Evaluation of the Optimum Transportation Investment in China and Its Impact on the Environment. *The Proceedings of the 37th Annual Meeting of Japan Section of the Regional Science Association International* (JSRSAI). (in Japanese).

Li, B. and Higano, Y., 2001a. Optimum Transport Investment under Environmental Restrictions: A Simulation of the Chinese Economy. *Studies in Regional Science*, 31(3), 63-77. (in Japanese).

Li, B. and Higano, Y., 2001b. The Energy Policy and Environment Policy in China toward the Sustainable Growth. *The Proceedings of the 38th Annual Meeting of Japan Section of the Regional Science Association International* (JSRSAI). (in Japanese).

Li, B. and Higano, Y., 2001c. Evaluation of the Optimum Transportation Investment in China and Its Impact on the Environment. Discussion Paper Read at *the 17th Pacific Conference of the Regional Science Association International* (PRSCO), (Discussant: Peter NIJKAMP), Portland, America, July.

Li, B. and Higano, Y., 2002a. The Anthropogenic Carbon Emission Management Policy in China That the Alternative Energy Was Taken into Consideration. *The Proceedings of the 39th Annual Meeting of Japan Section of the Regional Science Association International* (JSRSAI). (in Japanese).

Li, B. and Higano, Y., 2002b. Greening of the Energy System by Carbon Tax in China. Discussion Paper Read at *the 7th Summer Institute of Pacific Regional Science Conference Organization* (PRSCO), Bali, Indonesia, June, CD-ROM.

Li, B. and Higano, Y., 2003a. Countermeasures against Global Warming in China Known as a Developing Country: In the View of the Development of Green Energy Industry. *The Proceedings of the 40th Annual Meeting of Japan Section of the Regional Science Association International* (JSRSAI). (in Japanese).

Li, B. and Higano, Y., 2003b. An Eco-Model to Introduce Technology of Alternative Energy and to Establish Symbiosis Taxation System in China. *The Proceedings of the 6th Annual Meeting of Japan Association for Human and Environment Symbiosis* (JAHES). (in Japanese).

Li, B. and Higano, Y., 2003c. An Eco-conscious Socioeconomic Framework Model for Reducing Global Warming in China. Discussion Paper Read at *the 18th Pacific Conference of the Regional Science Association International* (PRSCO), Acapulco, Mexico, July, CD-ROM.

Li, B. and Higano, Y., 2003d. Derivation of an Optimal Carbon Tax Rate and Its Influence on Industrial Sectors Regarding Global Warming Prevention in China: Aiming the Encouragement of Alternative Energy Industry. Discussion Paper Read at *the 50th Anniversary Meeting of the Regional Science Association International* (RSAI), Philadelphia, America, November.

Li, B. and Higano, Y., 2004a. Countermeasures against Global Warming in China: From the View of Point of Encouragement of Green Energy. *Studies in Regional Science*, 34(1), 117-138. (in Japanese).

Li, B. and Higano, Y., 2004b. An Eco-Model to Introduce Technology of Alternative Energy and to Establish Symbiosis Taxation System in China. Forthcoming, *Journal of Japan Association for Human and Environment Symbiosis*, 10. (in Japanese).

Li, B. and Higano, Y., 2004c. Integrated Evaluation of Optimal Carbon Tax Policy by Means of Environmental Value-added in China. Forthcoming, *Studies in*

Regional Science, 34(2).

Li, B. and Higano, Y., 2004d. Simulation Analysis of the Effect of Introducing Carbon Tax: Considering an Alternative Energy in China. *The Proceedings of the 41th Annual Meeting of Japan Section of the Regional Science Association International* (JSRSAI), CD-ROM. (in Japanese).

Li, B. and Higano, Y., 2004e. The Anthropogenic Carbon Emission Management System and Environmental Partnership for the Sustainable Development in China. *The Proceedings of the 27th Annual Meeting of Japan Association for Planning Administration* (JAPA). (in Japanese).

Li, B. and Higano, Y., 2004f. An Environmental Socioeconomic Framework Model for Adapting Climate Change in China. Discussion Paper Read at *the World Conference 2004 of the Regional Science Association International* (RSAI), Port Elizabeth, South Africa, April.

Li, Z.D., 2003. An Econometric Study on China's Economy, Energy and Environment to the Year 2030. *Energy Policy*, 31(11), 1137-1150.

Li, Q., 1999. Analysis of China's Energy Demand. *A Dissertation Presented to the Graduate School of Management and Public Policy*, *University of Tsukuba*, Japan, 52 pp.

Lin, Y.H., 2001. Measures to Conserve Energy in China: In Line with that in Japan. *Research on Policy Sciences of Doshisha University*, 3, 277-292. (in Japanese).

LINDO Systems Incorporation, 1995. *LINGO User Guide*. LINDO Systems Incorporation, Chicago, Illinois, USA, 311 pp.

Liu, W.Q., Ganb L. and Zhang, X.L., 2002. Cost-competitive Incentives for Wind Energy Development in China: Institutional Dynamics and Policy Changes. *Energy Policy*, 30(9), 753-765.

Martin, W., 1993. Modeling the Post-reform Chinese Economy. *Journal of Policy Modeling*, 15(5/6), 545-579.

Matsui, K., 2000. *Energy Economy and Policy Theory*. Sagano Press, Tokyo, Japan, 122 pp. (in Japanese).

Ministry of the Environment in Japan, 2004. Proceedings Summary and Minutes of Comprehensive Policy and an Earth Environment Joint Section of the Central Environment Council. Via Internet: *http://www.env.go.jp/council/16pol-ear/yoshi16.html*, Read on 14, November 2004. (in Japanese).

Miyazawa, K., 1995. *Guide to Input-output Analysis*. Japan Economical Newspaper

Press, Tokyo, Japan, 216 pp. (in Japanese).

Mizunoya, T. and Higano, Y., 1999. Air Pollutants Emission Reduction and the Optimal Tax-Subsidy Policy for Japan. *Studies in Regional Science*, 30(3), 85-104.

Moffat, I. and Hanley, N., 2001. Modeling Sustainable Development: Systems Dynamic and Input-Output Approaches. *Environmental Modeling & Software*, 16(6), 545-557.

Mori, S., 1992. *Earth Environment and Resources Problem*. Iwanami Press, Tokyo, Japan, 157 pp. (in Japanese).

Morotomi, T., 2000. *Theory and Practice of Environmental Taxes*. Yuhikaku Press, Tokyo, Japan, 325 pp. (in Japanese).

Muto, S., Morisugi, H. and Ueda, T., 2003. Measuring Market Damage of Automobile Related Carbon Tax by Dynamic Computable General Equilibrium Model. *The Proceedings of the 43th Congress of European Regional Science Association* (ERSA), CD-ROM.

National Research Council, Chinese Academy of Sciences and Chinese Academy of Engineering, 2000. *Cooperation in the Energy Futures of China and the United States*. National Academy Press, Washington, DC, USA, 108 pp.

Ng, C.T., A Learning-by-doing Energy Model Based on Dynamic Programming. International Institute for Applied Systems Analysis, Interim Report IR-03-048, 1-21 pp. Via Internet: *http://www.iiasa.ac.at/Publications/Documents/IR-03-048.pdf*, Read on 30, March 2004.

Nishiyama, T., 2001. *An Earth Energy Theory*. Ohm Press, Tokyo, Japan, 151 pp. (in Japanese).

Nijkamp, P., 1977. *Theory and Application of Environmental Economics*. North Holland Publishing Company, Amsterdam, Holland, 332 pp.

Nordhaus, D.W., 1979. *The Efficient Use of Energy Resources*. Yale University Press, New Haven, Connecticut, USA, 161 pp.

Organization for Economic Co-operation and Development (OECD), 1999. *Environmental Taxes: Recent Developments in China and OECD Countries*. OECD, Paris, 327 pp.

Organization for Economic Co-operation and Development (OECD), 2002. *Environmentally Related Taxation System: The Evaluation and Strategies*. Translated from the English Edition of ‘Environmentally Related Taxes in OECD Countries: Issues and Strategies’, Translated by Environmental Taxes

Study Group of Synthesis Environment Policy Department of Ministry of Environment in Japan, (Eds.) Amano, A., Yuhikaku Press, Tokyo, Japan, 225 pp. (in Japanese).

Patlis, J.M., 2002. A Rough Guide to Developing Local Laws for Natural Resource Management. Discussion Paper Read at *the 7th Summer Institute of Pacific Regional Science Conference Organization* (PRSCO), Bali, Indonesia, June, CD-ROM.

Research Institute for Development and Finance of Japan Bank for International Cooperation, 2000. *Energy Balance Simulations to 2010 for China and Japan*. Research Institute for Development and Finance of Japan Bank for International Cooperation, Tokyo, Japan, 117 pp. (in Japanese).

Rufin, C., Rangan, U.S. and Kumar, R., 2003. The Changing Role of the State in the Electricity Industry in Brazil, China, and India. *American Journal of Economics and Sociology*, 62(4), 649-676.

Sakurai, K., 2004. Research on the Synthetic Management Policy of the Kasumigaura Valley Environment. *A Doctoral Dissertation Presented to the Graduate School of Life and Environmental Sciences, University of Tsukuba*, Japan, 168 pp. (in Japanese).

Satoh, M., 1998. An Analysis of Land Redistribution and Its Impact on Agricultural Practices in the Red River Delta. *Transactions of the Japanese Society of Irrigation, Drainage and Reclamation Engineering*, 196, 125-139.

Shaw, D.G., Farrington, J.W., Connor, M.S., Tripp, B.W. and Schubel, J.R., 2000. The Role of Environmental Scientists in Public Policy: A Lesson from Georges Bank. *Marine Pollution Bulletin*, 40(9), 727-730.

Shi, M.J., Tanaka, Y. and Zhao, H.L., 1998. Sustainable Development of Land Use and Farming System for Combating Desertification in Horqin Sandy Land: A Case Study on Naiman Banner, Inner Mongolia, North China. *The Proceedings of Japan-China Workshop on Land Evaluation of Prevention and Remedies for Desertification*.

Sinton, E.J. and Fridley, G.D., 2000. What Goes up: Recent Trends in China’s Energy Consumption? *Energy Policy*, 28(10), 671-687.

Takahashi, K., 1999. *Correspondence to Globalization*. Foundation for Advanced Studies on International Development, Tokyo, Japan, 169 pp. (in Japanese).

Tao, K., 2001. *Interindustry Study on the Chinese Economy*. Keisuisha Co., Ltd, Hiroshima, Japan, 609 pp. (in Japanese).

Tangen, K. and Heggelund, G., 2003. Will the Clean Development Mechanism Be

Effectively Implemented in China? *Climate Policy*, 3(3), 303-307.

Toyoda, T., 2003. *Agricultural Policy*. Nihon Keizai Hyoronsha Press, Tokyo, Japan, 211 pp. (in Japanese).

Wang, S.Q., Zhou, C.H., Liu J.Y., Tian, H.Q., Li, K.R. and Yang, X.M., 2002. Carbon Storage in Northeast China as Estimated from Vegetation and Soil Inventories. *Environmental Pollution*, 116(1) Supplement, S157-S165.

Webster, M., Forest, C., Reilly, J., Babiker, M., Kicklighter, D., Mayer, M., Prinn, R., Sarofim, M., Sokolov, A., Stone, P. and Wang, C., 2003. Uncertainty Analysis of Climate Change and Policy Response. *Climate Change*, 61(3), 295-320.

Xu, Z.M., Cheng, G.D., Chen, D.J. and Templet, H.P., 2002. Economic Diversity, Development Capacity and Sustainable Development of China. *Ecological Economics*, 40(3), 369-378.

Yagita, H., Kondo, Y., Kobayashi, M. and Inaba, A., 2000. A Comparative Evaluation of CO_2 Mitigation Options for Japan Using the NICE Model. *Japan Energy Society*, 79(2), 118-128. (in Japanese).

Yan, C.L., (Eds.), 2002. *China Energy Development Report 2001*. China Jiliang Press, Beijing, China, 314 pp. (in Chinese).

Yan, J.H. and Higano, Y., 2001. The Carbon Tax Taxation System for the Alternative Energy Introduction Promotion in China. *The Proceedings of the 38th Annual Meeting of Japan Section of the Regional Science Association International* (JSRSAI). (in Japanese).

Yao, H.T. and Nobukuni, M., 2002. China's Long-term Economic Development and Demand of Energy. *Studies in Regional Science*, 32(1), 45-61. (in Japanese).

Zbaracki, M.J., Ritson, M., Levy, D., Dutta, S. and Bergen, M., 2004. Managerial and Customer Costs of Price Adjustment: Direct Evidence from Industrial Markets. *The Review of Economics and Statistics*, 86(2), 514-533.

Zhang, Z.X., 2000. Decoupling China's Carbon Emissions Increase from Economic Growth: An Economic Analysis and Policy Implications. *World Development*, 28(4), 739-752.

Zhu, R.Z., 2001. *Formation and Distribution of Wind Power Resources in China*. China Meteorological Press, Beijing, China, 38 pp. (in Chinese).