The Composite Impact of the Low-Carbon Development Policies in Beijing's Urbanization: A Regional Dynamic CGE Modeling

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Abstract

The transition to a low-carbon economy, originated from the thinking on the energy future, climate change and sustainable development, has gained global momentum in recent decade. China in the industrialization and the urbanization process has to find an effective and inclusive strategy with policy mix for the low-carbon development. The research on the policies and planning for low-carbon development in China and as well Beijing is accordingly becoming a frontier of policy concerns.

This report aims to highlight the offsetting and the synergy effects in terms of economic growth, energy consumption, and carbon emission by industry of policy pair by quantifying the impact of different low-carbon development policies. As supported by the GEF for the Second Beijing Environment Project, we take Beijing as a case to analyze counter-facturally the cost effective policy mix for low-carbon development in urbanization with a dynamic CGE model. This model is a SAM-based regional one, which follows the assumptions of energy consumption and CO2 emission by industries of the GRACE model by CICERO in Norway, the assumptions of commodity flows out-and-in of Beijing as depicted in the PRCGEM model by the IQTE Team at CASS. The policies in the designed scenarios include: (1) A flat increase in energy efficiency by industry; (2) An increase in investment in electricity industry; (3) A flat carbon tax by industry; (4) A policy pair, i.e a mix of carbon tax and investment subsidy for energy conservation and emission reduction to keep the governmental revenue neural.

The conclusion is that the cost effective low-carbon development strategy should be one on the integrated application of practical policies.

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1. Introduction

The high-carbon economic development after the Industrial Revolution has directly resulted in the global warming effect, which has widely attracted the attention from the international societies. For establishment of a global climate change institution system, the UK government put firstly forward the concept of low-carbon economy in 2003. In February 2003, the UK Primer Minister Blair delivered a white paper titled *Our Energy Future: Creating a Low-Carbon Economy*, in which the UK government planned to reduce the CO2 emission by 60% in 2050 over that in 1990 so as to establish a low-carbon economy and society. In October 2006, it was pointed out in Stern Report, directed by Lord Nicholas Stern, the chief economist of the World Bank that 5%-20% of GDP loss could be avoided each year if 1% of the world GDP was inputted for "energy saving and emission reduction"; it hence called for global transition to a low-carbon economy. Such countries as France, Japan and Canada etc. have adopted practical policy measures. The United States has not publicly expressed its acceptance of the concept of low-carbon economy, but it has constantly insisted on adaptation to the climate change and mitigation of CO2 emissions with technical progress, which is consistent to the connotation of low-carbon economy.

The low-carbon economy is in some way an economy with high energy efficiency and clean energy structure. To develop low-carbon economy requires in fact the energy technology and institutional innovations. The goals of developing low carbon economy are deceleration of climate change and promotion of sustained development. The transition to the low-carbon economy has become a global trend for a new economic development pathway.

Before Copenhagen Summit Meeting, the Chinese government stated that it would reduce the CO2 emission per unit of GDP by 40%-50% in 2020 over that in 2005. On the 15th APEC leaders' meeting held on September 2007, President Hu Jingtao explicitly stated that China would "develop the low-carbon economy", which attracted the global attention. Hu emphasized the development of low-carbon economy, including exerting efforts on the research and development and promotion of low-carbon energy technologies, increasing carbon sequestration and developing carbon capture and storage technologies. Ministry of Science and Technology of the PRC called later for the great efforts for the development of low-carbon economy on the 9th Annual Meeting of China Association for Science and Technology in 2007. The development of low-carbon economy has become a new mode for China's social and economic development. On August 2010, the NDRC started the experiment work by allowing for sampling provinces and cities in China to develop low carbon economies. The sampling provinces and cities include five provinces, ie. Guangdong, Liaoning, Hubei, Shaanxi, Yunnan, and eight cities, ie.,Tianjin, Chongqing, Shenzhen, Xiamen, Hangzhou, Nanchang, Guiyang and Baoding. The governments from these sampling provinces and cities promised to study and make up their low-carbon development plans, accelerate the establishment of industrial systems that take the low carbon emission as their features, and actively encourage the low carbon green living and consumption modes so as to make contributions to the global challenge to the climate change.

Beijing, the Capital of the P.R. China, with the constant growth of population and economic scale, is facing the environmental challenges caused by the energy consumption, which forces Beijing to reduce the resource consumption intensity and improve the resource utilization efficiency by adoption of comprehensive legal, economic and administrative measures in a cost-effective framework. The main emission sources of greenhouse gas in Beijing are mainly the energy consumption and the main emitted gas is CO2. The core factor for driving the growth of Beijing's CO2 emission is the rapid economic growth while the main modes for inhibiting the growth of CO2 emission are reduction of energy consumption intensity and adjustment of industrial structure. In 2006-2008, the energy intensity of Beijing decreased successively for three years up to 17.53%.

The low-carbon development of an economy involves various fields such as economy, society, population, resources and environment and is a complicated system. While multiple market failures call for multiple policies, different low-carbon development policy mixes usually interact in different ways and have usually different impacts on the grounds of cost-effectiveness, and related policy action would deeply affect the social and economic development. While some policy mix is beneficial to economic development but harmful to energy saving and emission reduction, some other policy mix may contribute to energy saving and emission reduction but restrain economic development. While the effect of some policy mix is amplified by their combination, some other policy mix may have offsetting or complementarities impacts. Accordingly, a coherent framework is required to integrate and quantify the combined effect of different policy and measure mixes for low-carbon development in terms of cost effectiveness.

To coherently and quantitatively assess the different impacts of policy mix for low-carbon development, various simulation models have been developed. However, computable general equilibrium (CGE) models are widely used because of their coherent framework based on input-output or social accounting matrix (SAM) database, the underlined interaction of multi-markets, the theoretical optimization behaviors for multi-sectors and macroeconomic agents, and multiple policy instruments that function through market mechanisms. CGE modeling is used as a standard practice for counter-factural analysis of economic policies and measures on the grounds of cost-effectiveness.

We built a SAM-based dynamic CGE model for Beijing's low carbon development policy analysis. The model is used to assess the composite effect of different abatement policies.

2. The Beijing's Dynamic CGE Model

For modeling and counter-factural analysis of Beijing's low-carbon development policies, a dynamic CGE model for Beijing is built by tailoring the PRCGEM (Fan and Zheng,1998) and the Grace (Aaheim and Rive, 2005) and Thurlow (2008). The Beijing CGE model is calibrated based on the Beijing SAM in 2005, which is compiled including 42 industries, four kinds of macroeconomic agents, ie. the households, the enterprises, the governments that be disaggregated into local and central governments, and the rest regions that be disaggregated into rest of domestic regions and rest of the world. The Beijing CGE model is specified for model simulations and quantitative assessment the combined effects of Beijing's low carbon development policies.

2.1 The benchmark Database for the Beijing CGE Model

A SAM of the economy provides a comprehensive and consistent standard database for CGE model. SAM uses the matrix form to represent the transactions between activities by industry, commodities, factors, institutional agencies, and capital account in the system of national accounts, and to depict various economic linkages of social and economic agents in certain period. The rows of SAM respectively represent the associated income from the related columns.

Table 1 shows the theoretical structure of the macro SAM in Beijing, including activities, commodities, factors, households, enterprises, Beijing government, central government, investment and savings, other regions in China and abroad. The Beijing SAM is characterized with five aspects: (1) The government sector is decomposed into municipal and central governments, which allows for transfer relation between governments; (2) The trade transaction is decomposed into transaction between domestic regions and transaction between Beijing and other economies abroad; (3) The industry sector can be divided into energy industries and non-energy industries, industries with high energy consumption and industries with low energy consumption, for convenience of scenario building and simulations; (4) The energy industries are detailed, which allow for studying consumption of various specific energies and substitution relation among different energies; (5) Given the transportation industry is the key consumer of energies in Beijing, the transportation industry is decomposed in details. Table 2 provides the Beijing macro SAM in 2005. The data source is listed in Table 3.

The macro SAM is decomposed into micro SAM with 42 industries, which can be further decomposed into 53 industries that include 9 energy industries and 8 industries of transportation, see Annex 1.

The macro and micro SAMs are balanced by using the Cross-Entropy method developed by Robinson, et al (2001).

Table 1. The Theoretic Structure of the Beijing's Macro SAM

	Activities	Commodities	Factors	Households	Enterprises	Beijing Government	Central Government	Investment-Saving	Rest of China	ROW	TOTAL
Activities		Marketed outputs									Gross Output
Commodities	Intermediate inputs	Transaction costs		Household consumption		Government Consumption		Investment	Domestic Export	ROW Export	Gross Demand
Factors	Value added									Factor income from ROW	Factor Income
Households			Factor income to households	Inter-household transfers	Transfers to Households	Transfers to Households				Transfers from ROW	Households Income
Enterprises			factor income to enterprises			Transfers to enterprise				transfers to enterprises from ROW	Enterprise Income
Beijing Government	VAT and Production taxes	Sales taxes, tariffs, export taxes	Factor income to government	Income taxes and Transfers to Beijing government	Income taxes and Transfers to Beijing Government		subsidies and transfers			Transfers from ROW Governments	Beijing Government Income
Central Government						Transfers to central governments					Central government income
Investment-Saving				Household saving	Enterprise Saving	Beijing government saving	Central government saving		Saving from ROC	Foreign savings	Gross Saving
Rest of China		Imports from ROC									Inflow from Rest of China
ROW		Imports from ROW	factor income to ROW		Transfers to ROW	Transfers to ROW					Foreign exchange outflow
TOTAL	Activity Inputs	Gross Supply	Factor expenditures	Household expenditures	Enterprise expenditures	Beijing Government expenditures	Central government expenditure	Total investment	Inflow to rest of China	foreign exchange inflow	

Table 2. The Macro SAM of Beijing in 2005 (0.1 billion Yuan)

	Activities	Commodities	Labor	Capital	Enterprises	Households	Beijing Government	Central Government	Income Taxes	Production Taxes	Investment-Saving	Stock Changes	Rest of China	ROW	TOTAL
Activities		20820.2													20820.2
Commodities	13898.2					2248.0	1291.5				3204.7	378.3	4535.1	2749.5	28305.2
Labor	3114.2														3114.2
Capital	2789.5														2789.5
Enterprises				2789.5											2789.5
Households			3114.2		1750.0		8.8								4873.0
Beijing Government								1976.5	19.9	1018.3					3014.6
Central Government							430.3								430.3
Income Taxes					11.4	8.4									19.9
Production Taxes	1018.3														1018.3
Investment- Saving					1028.1	2616.5	1282.5	−1546.2					334.9	−132.9	3582.9
Stock Changes											378.3				378.3
Rest of China		4870.1													4870.1
ROW		2615.0					1.6								2616.6
TOTAL	20820.2	28305.2	3114.2	2789.5	2789.5	4873.0	3014.6	430.3	19.9	1018.3	3582.9	378.3	4870.1	2616.6	

Source: Authors' estimation

Table 3. Data Source of Beijing Macro SAM

	Data Sources
Enterprise's transfers to Households	Balance of column
Beijing government transfers to households	Social security subsidy 2.5095 billion Yuan;pension and social aid,3.20515 billion Yuan, Policy allowance 0.46158 billion Yuan.
Households income taxation	Households income tax, 8.45232 billion Yuan.
Enterprise income taxation	Enterprise income taxation, 16.47615 billion Yuan.
Beijing Government direct Income taxation	Households Income taxation + Enterprise income taxation
Households saving	Balance of column
Enterprise saving	Balance of column
Beijing Government saving	Balance of column
Central government saving	Balance of column
Rest of China saving	Balance of column
Foreign saving	Balance of column
Beijing transfers to ROW	Expenditure of foreign affair 0.01597 billion Yuan; Foreign aid, 7.407 billion Yuan; Interest of foreign loans, 3.536 billion Yuan; Payment to foreign loans, 4.486 billion Yuan.
Beijing Government transfer to Central government	Turnover to central government 4.30229 billion Yuan.
Central government transfers to Beijing government	Central government subsidy, 19.77709 billion Yuan.

Source: China Statistical Yearbook of Finance (2006);

In addition to SAMs, various parameters for the Beijing CGE modeling are calibrated, including share parameters, conversion parameters, various tax rates in revenue module, household's marginal propensity to save, etc. Various elasticities, including substitution elasticity of production factors, income elasticity of household demand, elasticity of trade transformation, are directly given by referring to some empirical estimations.

In current analysis, the Beijing CGE model also requires sub-sector carbon emissions data. In order to get carbon emissions data, we follow the approach by Lee (2007) to consider only the process of production and consumption of fossil energy and associated carbon emissions through a fixed connection coefficient between them.

2.2 The Beijing dynamic CGE Model

The Beijing dynamic CGE model follows the standard pattern. Figure 1 provides a bird's eye of the flow of commodities and factors. Figure 2 shows the production technology.

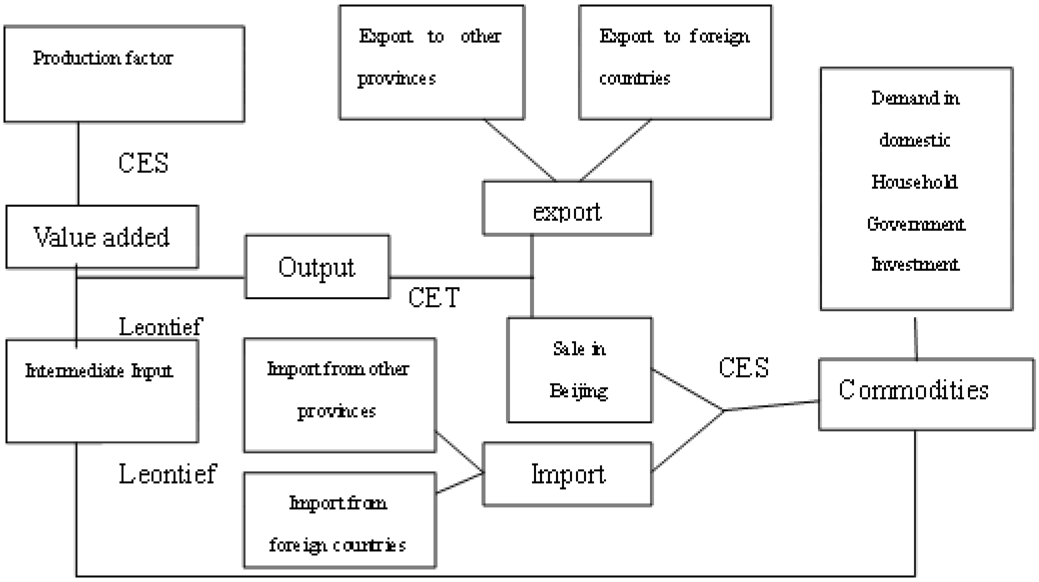

Figure 1. Flow of Commodities and Factors

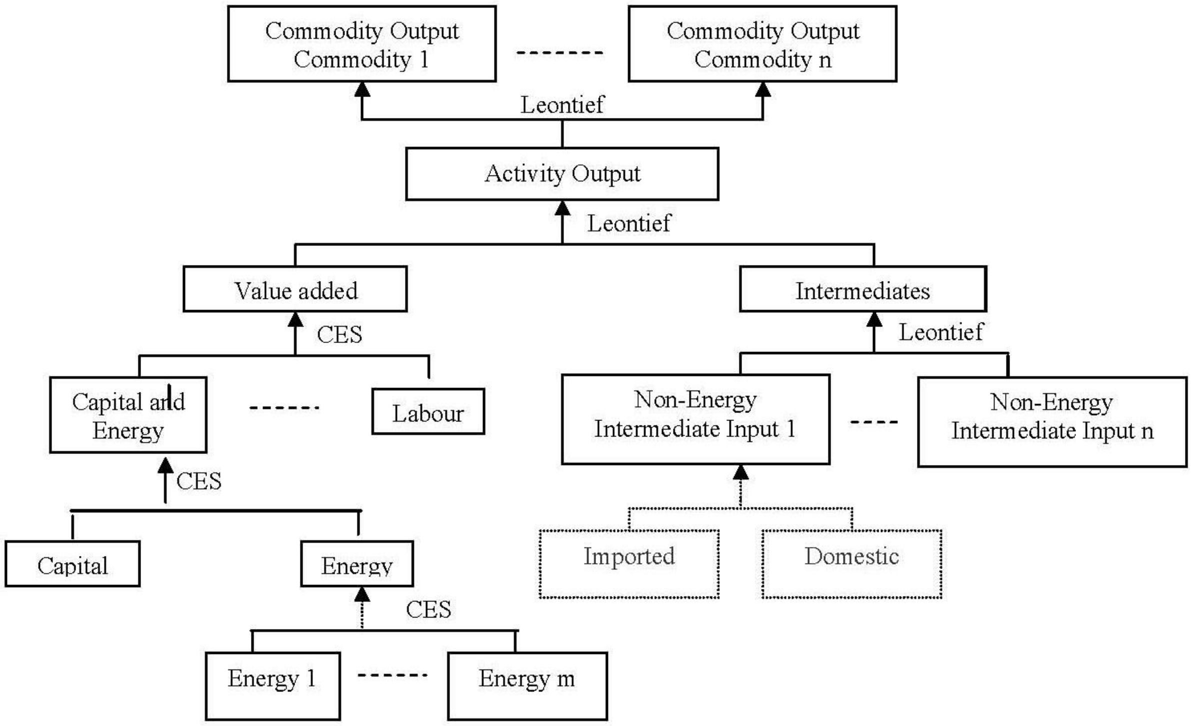

Figure 2. Production Technology

Figure 3 represents the commodity flow from market supply to final demand. Figure 4 represents the income and expenditure flow.

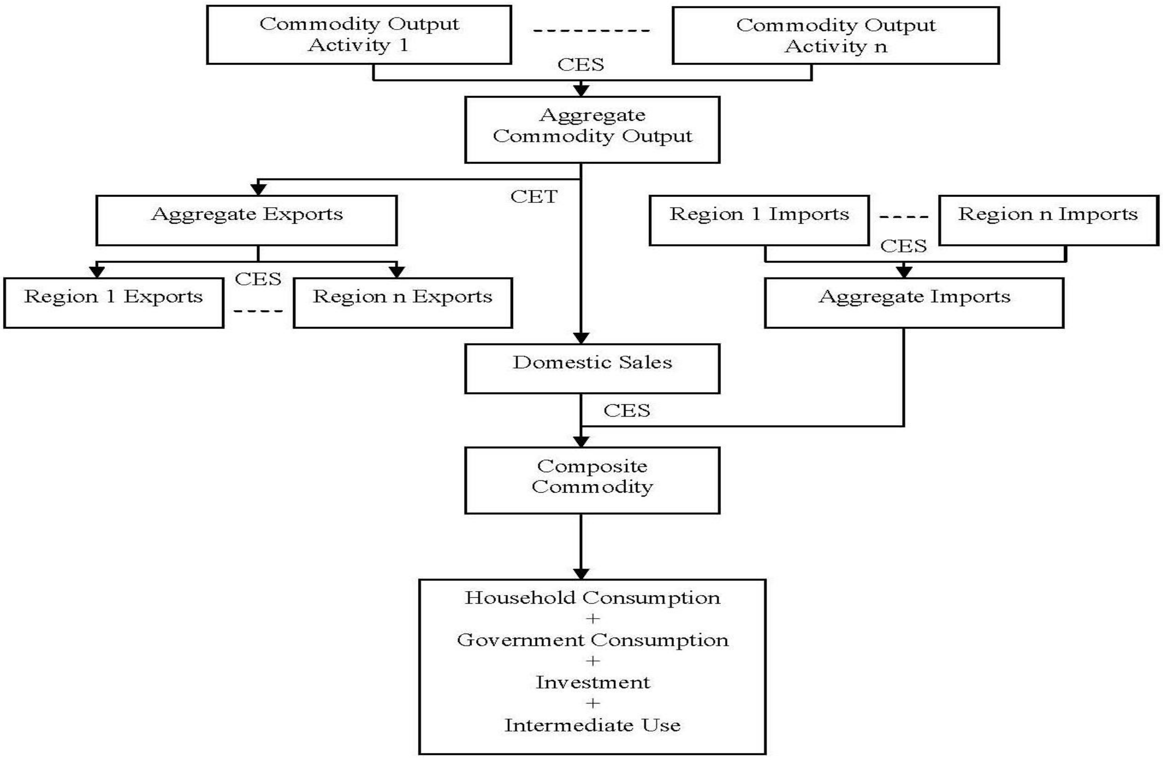

Figure 3. Commodity Flow

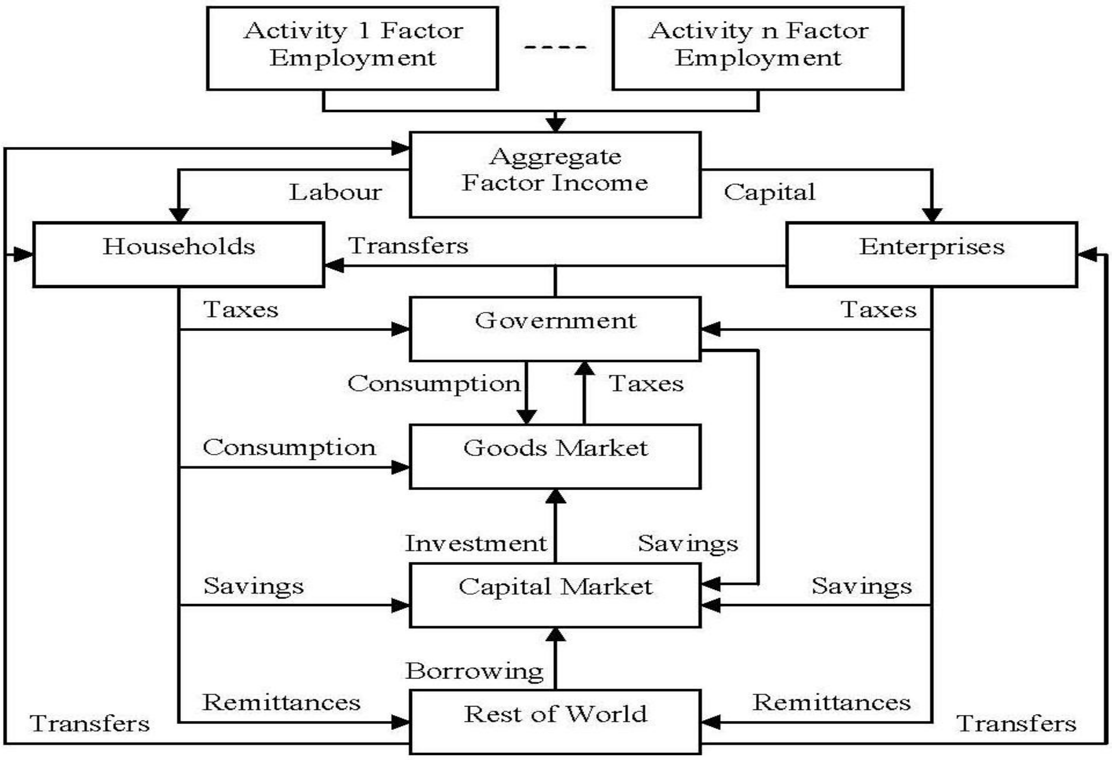

Figure 4. Institutional Incomes and Domestic Demand

The Beijing model is a recursive dynamic one, which implies that the dynamics is actually obtained by solving a set of sequential series of static model. In particular, the proportion of inter-sectoral allocation of capital is adjusted through the ratio of sector profit margin and the overall average profit margin.

3. Modeling and Analysis of Low-carbon Development Policies of Beijing

Despite the compilation of Beijing 2005 SAM at 53 industries, however, we now only use the 42-sector Beijing 2005 SAM and the corresponding dynamic CGE model for the simulation of low-carbon development policy.

3.1 Building Policy Scenarios for Beijing's Low-Carbon Development

In order to analyze the affect of energy and environmental policies on the economy and carbon emissions in Beijing, this study established the Beijing recursive dynamic CGE model, which took 2005 as the base year, and applied the model to dynamically simulate the impacts on economic development and carbon emissions of policy scenarios. Simulation scenarios include the baseline scenario and the policy scenarios. The baseline scenario simulation provides the benchmark projection by assuming business as usual (BAU) for economic and carbon emission conditions and no changes in the considered policies, which functions as the benchmark for comparison with the policy simulations of the built-in scenarios. The policy scenarios simulations provide a comprehensive assessment of various policies on energy use, carbon emissions, employment, economic growth and structural transformation. The diversions of the economic and carbon emission changes between the BAU with policy changes and the BAU without policy changes measure the impacts of policies for Beijing's low-carbon development, providing optimized options for Beijing to develop various policies.

3.1.1 Baseline Scenario

Baseline scenario provides a comparable baseline for the policy scenarios. The study adopts baseline scenario assumptions, considering urban development planning and recent population and economic trends of Beijing. In the benchmark 2005, Beijing per capita GDP was 45,993 Yuan (equivalent to US$ 5,615) (Beijing Statistical Yearbook, 2010). We assume in the baseline scenario, Beijing per capita GDP (GDP in 2005) will reach US$ 16,617.75, US$ 25,683.63 respectively in 2012 and 2020, 2.17 times, 3.13 times of 2005, with the average annual increase of 8.04% and 7.90% respectively; 2005-2020, the Beijing GDP average annual growth is about 10.1%, to achieve mainly in the model equations by adjusting total factor productivity (TFP) in the production. However, the model does not set different technological progress rate for different industries, nor a breakdown of labor force.

3.1.2 Policy Scenarios

International communities expect China to take immediate action to limit or reduce carbon emissions. China has promised to set in the main carbon intensity of energy consumption and the proportion of non-fossil fuels. Copenhagen in 2009, United Nations Framework Convention on Climate Change, the eve of the 15th meeting of the Parties, the Chinese Government's commitment to carbon emissions by 2020 compared to 2005 unit of GDP, down 40% -45%, and 2020, the share of non-fossil energy share of primary energy consumption increased to about 15%. To achieve these ambitious goals and to maintain sustainable development, as the capital of China, Beijing should make appropriate contribution in the above two goals.

At present, some scholars have applied CGE model to study China's energy consumption and carbon emissions related issues, such as “The impact of carbon tax in China” (Zhang 1998; Garbaccio et al. 1999; Wei and Glomsrød 2002; Liang et al. 2007), “China tariff reduction and WTO access” (Fan and Zheng 2001), “mid and long-term trend of energy intensity” (Li 2008), “Clean coal project effects” (Glomsrød and Wei 2005), “Impact of different climate policies on economy” (Wang et al. 2009), “To improve energy efficiency completely in energy use and CO2 emissions” (Liang et al. 2009). In all measures, scholars first recommend to improve energy efficiency (e.g. Gan 1998; Zhang 2008; Zhu et al. 2009; Li 2010). Recently, Glomsrød and Wei studied the problem of China's energy efficiency improvement (2010) with a global model. Although increasing energy efficiency will reduce energy consumption, it will also cause energy prices decline, resulting in more energy consumption and squeeze the saved energy consumption from energy efficiency improvement. This “Squeeze” effect is often called “rebound” effect in some literature, and has been debated for decades (Greening et al. 2000; Dimitropoulos 2007). However, on the other hand, the conservative position also cause for concern, for example, decreasing energy use is faster than increasing energy efficiency (Saunders 2008; Wei 2010). In fact it is estimated that since 1978, China has reduced 18 billion tons CO2 emissions through improved energy efficiency. To what extent if Beijing takes measures to help improve energy efficiency, then such measures will actually reduce energy consumption in Beijing? Will fossil fuel carbon emissions also be reduced? We analyze the above problems through Beijing CGE model. The improvement of energy efficiency has a greater impact on the economy, which expanded from a purely energy efficiency improvement throughout the economy and also affected commodity prices, production and consumption. Partial equilibrium and purely decomposition analyses are difficult to consider these combined effects (e.g., Peters et al. 2007; Zhu et al. 2009), but the CGE model can reflect the energy efficiency improvement brought about by the combined effects.

To employ the Beijing CGE model for policy scenario analysis, we build three kinds of scenarios.

First, a 5% increase in energy efficiency scenario. It is assumed that the energy efficiency improvement is exogenously shocked by 5%. The Beijing CGE model is then employed to quantify the percentage changes between with and without the policy shocks in the context of economic growth, energy consumptions and carbon emissions. In other words, the relevant endogenous variables are compared before and after the 5% increases.

The shock for the energy efficiency improvement is assumed to be 5% only for illustration purpose. Moreover, the sources of the energy efficiency improvement are neglected even though they may be quite diverse and matter as technical progress. For example, some new energy-saving equipment may be installed to improve energy efficiency; better management can lead to use energy in production or consumption more efficiently; sometimes just behavior adjustments of firms/households such as turning off the lamp or TV when they are not in use can also lead to certain energy efficiency gains. However, the source of energy efficiency improvement is beyond focus herewith.

Second, a 5% increase in investment in electricity scenario. To achieve a low carbon economy, another possible policy is to encourage more clean energy production and consumption. A feasible policy choice mentioned in the literature is to encourage power generation and electricity (e.g., Eskeland et al. 2008; Dianshu et al. 2010). As a result, an additional 5% of the capital stock of electricity is exogenously shocked to represent the investment in clean energy case.

Third, 35 Yuan tax per ton of carbon emission scenario. Carbon tax is a policy instrument that has been internationally explored for reducing carbon emission. Many scholars studied the impact of CO2 tax levy on the economy, but the results were quite different. Some believe that, to increase low carbon tax while reduce corporate tax appropriately can contribute to reducing carbon emissions and maintain long term economic growth. However, others argue that despite of the short and long term carbon emissions reduction, China would suffer great economic losses. For example, Zheng and Fan (1999) confirmed that CO2 emissions reduction would lead to a 1%-0.016% decline in China's economic growth, and the output would seriously decline in some industries (the losers) and only a few industries would keep slight economic growth. In this study, a carbon tax rate at 35 Yuan (about US＄5) per ton of carbon emission is exogenously imposed. This tax rate is very low compared to the market price of carbon. Although Carbon futures prices plunged in European Futures Exchange associated with the financial crisis, carbon was still traded at the moment above 20 Euro/ton CO2 (equivalent to US＄12/ton CO2). As seen, carbon price rose to 14 Euro/ton CO2 in July 2009 from 11 Euro/tone CO2 in March 2009 (Point Carbon 2009).

To develop low carbon economy in Beijing means to innovate in low carbon technology, change traditional lifestyle and minimize the municipal’s greenhouse gas emissions. It means to get rid of the past social and economic model of mass production, mass consumption and mass disposal, formalize a new system of structural optimization, recycling and energy efficient use system, ultimately realize the clean, efficient, low carbon and sustainable development in Beijing. Accordingly, this study can be expanded by improving the Beijing CGE model to timely simulate industrial policies that focus on the development of low energy consumption industries, while gradually phasing out high energy consumption industries. This study also can be extended to incorporate subside policies into the Beijing CGE model. Only by employing CGE based models can we simulate the comprehensive impacts of selective policy mix and provide quantitative advices identifying the winners and losers associated with policy mix.

3.2 The results of Beijing’s low carbon economic policy simulations

This part discusses the simulated results of the impact on economic growth, energy consumptions and carbon emissions from the above 3 scenario simulations.

3.2.1 5% increase in Energy Efficiency

(1) Economic effects

After the 5% increase in energy efficiency in 2011 is introduced, the economic growth is encouraged and Beijing's GDP in 1015 and in 2020 would deviated from the reference scenario by 1.3% and 1.2% respectively, which is much less than the 5% increase in energy efficiency. By 2020, the rural households' consumption would increase by 1.4%, urban households' consumption by 1.3%, government consumption by 1.1%, and capital formation by 1.1%. Figure 5 shows the changes in consumptions and investments by goods after the 5% increase in energy efficiency is introduced. On one hand, energy consumptions by both rural and urban households would reduce due to the increase in energy efficiency. On the other hand, increase in energy efficiency would encourage aggregate consumption and aggregate investment. Almost all of the industries would benefit from the 5% increase in energy efficiency.

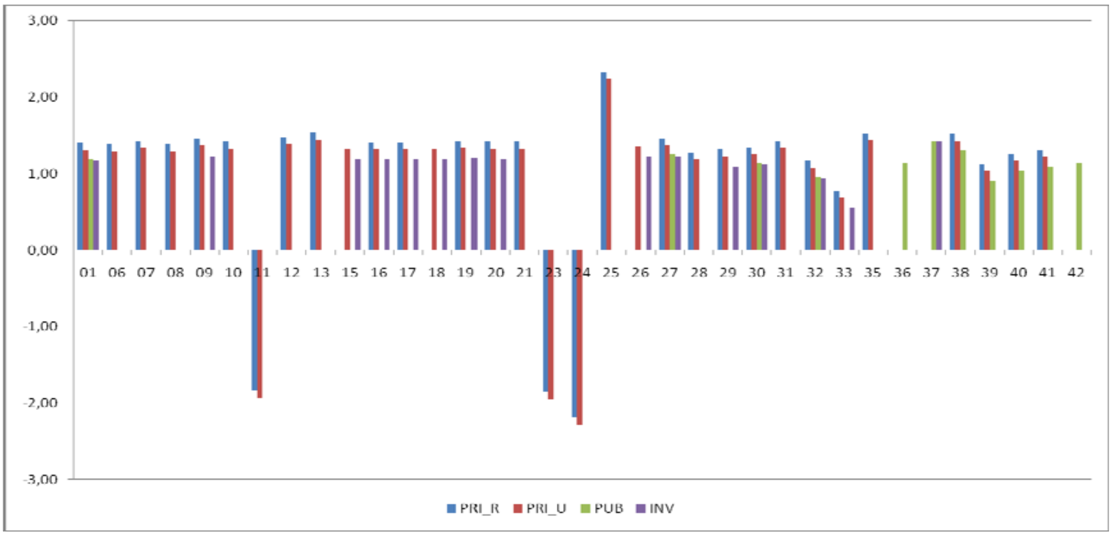

Figure 5. % changes in consumption and investment by industry in 2020

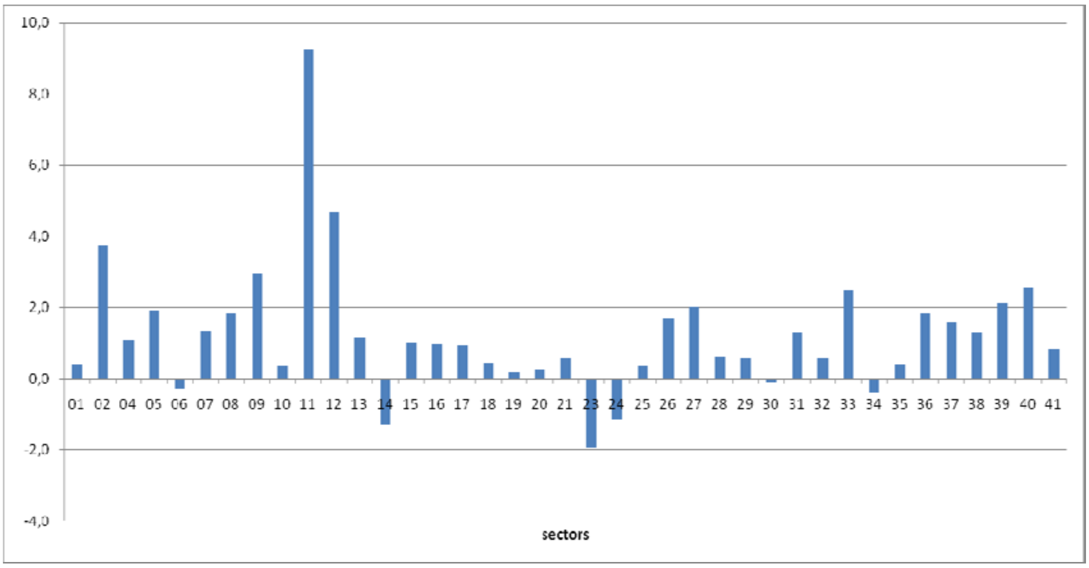

Figure 6. % changes in industrial value added in 2020

Figure 6 shows the percentage deviation from the reference scenario of industrial value added in 2020. The 5% increase in energy efficiency would result in decrease in prices of production inputs, which implies higher share of value added in total output for almost all of the industries.

The increase in energy efficiency would have different effects on the energy production industries. In 2020, the production of coal and refined oil would be encouraged and would increase by 3.7% and 9.3% respectively. However, the production of electricity and natural gas would be discouraged and would decrease by 2.0% and 1.1% respectively. There is no extraction activity of crude oil in Beijing. As a result, the increase in energy efficiency in Beijing would make dirty energy production such as coal mining and refined oil benefit more, and result in production losses of relatively clean energy such as electricity and natural gas in the local market.

(2) Energy consumptions

The 5% increase in Beijing's energy efficiency would result in decrease in total energy consumption in Beijing. In 2020, total final consumption of coal and crude oil would decrease by 2.7%, gas by 2.1%, refined oil by 1.2%, and electricity by 1.0% when compared with the reference scenarios. However, the production of coal, refined oil, and electricity in Beijing would increase. It must imply that more of these energy goods would have to export to rest domestic regions or rest of the world. The underlying mechanism is that the 5% increase in energy efficiency would result in decreasing in local prices of energy goods, which implies relatively increasing prices in the external regions. The decreasing in local prices of energy goods would also discourage the imports of these energy goods from the external regions, which would make Beijing achieve higher economic growth from increasing in net exports.

Total coal consumption would decrease the most in the five energy goods. Figure 7a shows % changes in coal consumption by industries in 2020. The 5% increase in energy efficiency would have all industries but refined oil and chemistry industries reduce their coal consumptions.

On the contrary, total electricity consumption would decrease the least in the five energy goods. Figure 7b shows % changes in electricity consumption by industries in 2020. Compared to the case of coal consumption, there is one more sector, the processing of timbers and manufacture of furniture industry, would consume more electricity while other industries would basically follow the same direction as the coal consumption case after the 5% increase in energy efficiency is introduced in Beijing.

The impact on the consumption of refined oil by industry is also estimated. Figure 7c shows % changes in refined oil consumption by industries in 2020. All but three industries would consume less refined oil after the 5% increase in energy efficiency is introduced. The three industries are the processing industry of timbers and manufacture of furniture, chemical industry, and health， social security and social welfare industry. This also would contribute to reduction in carbon emission in Beijing.

Hence, energy efficiency gains may not always lead to reduction of energy consumption for all industries.

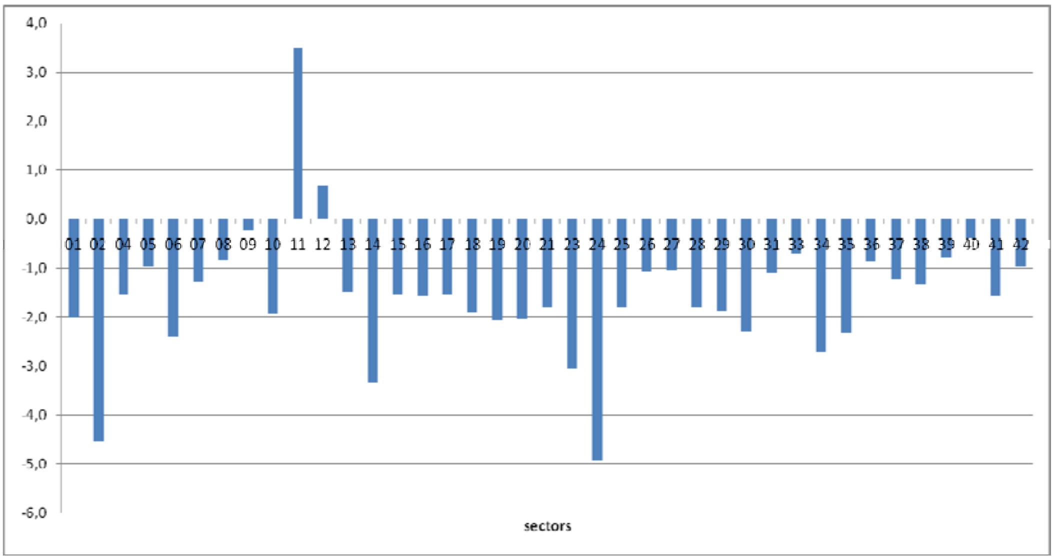

Figure 7a. % changes in coal consumption by industries in 2020

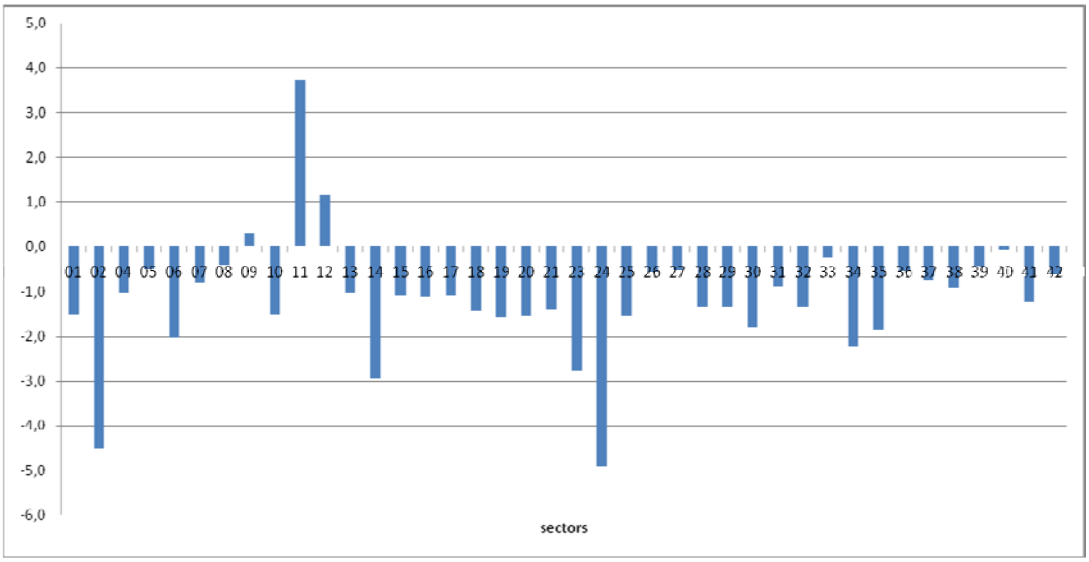

Figure 7b. % changes in electricity consumption by industries in 2020

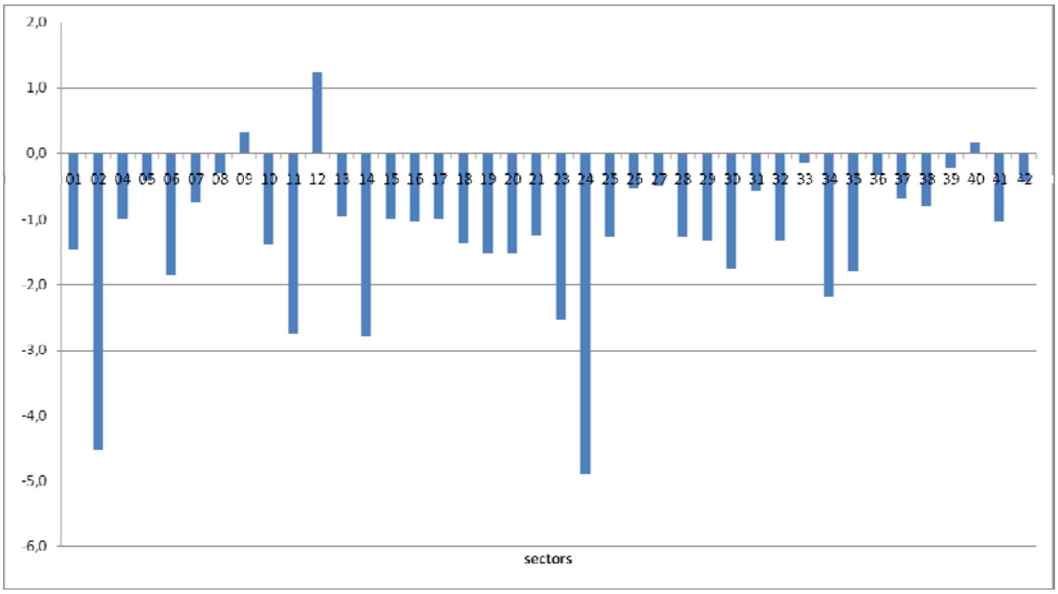

Figure 7c. % changes in refined oil consumption by industries in 2020

(3) Carbon emissions

After the 5% increase in energy efficiency is introduced in Beijing, total carbon emission would reduce by 2.0%, which is much less than the 5% increase in energy efficiency. The expectation that carbon emission would reduce at the same rate as the energy efficiency gain is very misleading because there is strong rebound effects on energy consumption and carbon emissions by way of lower prices of energy services associated with energy efficiency gains.

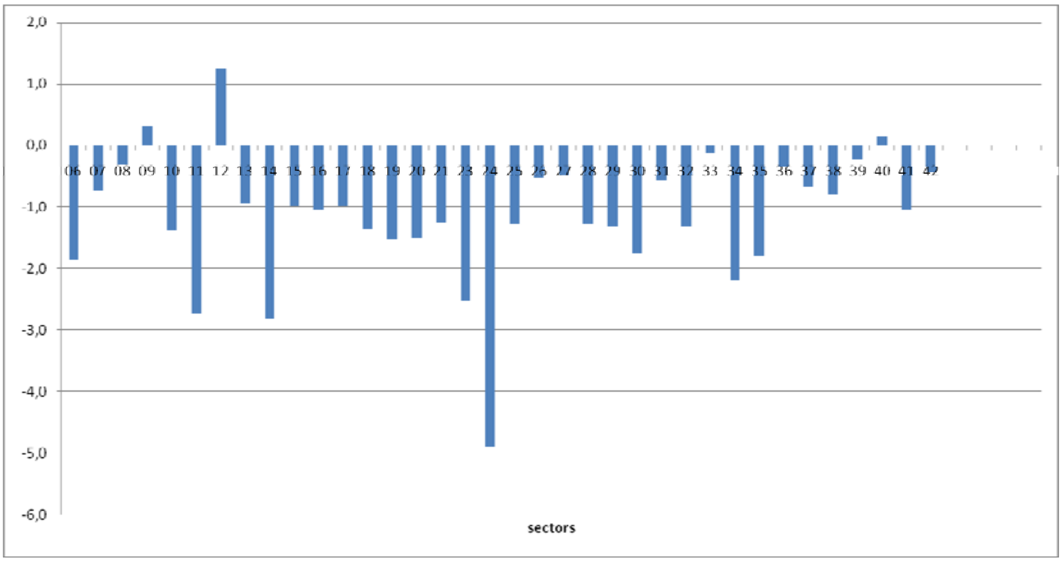

Figure 8. % changes in carbon emissions by industries in 2020

When coming to carbon emissions by industries as shown in Figure 8, all but two industries would have less carbon emissions. The two industries are the processing industry of timbers and manufacture of furniture and chemical industry. At the aggregate level in Beijing, the 5% increase in energy efficiency in Beijing would contribute to the reduction of total carbon emission, which is basically true at the industrial level.

3.2.2 5% increase in investment in electricity industry

(1) Economic effects

If a 5% increase in capital stock in electricity industry is assumed, the economic development is encouraged and GDP of Beijing in both 2015 and 2020 would increase only by 0.1% compared with the reference scenario cases. In 2020, the consumption of rural households and urban households would increase only by 0.10%, the government consumption by 0.11%, and investment by 0.08%.

Figure 9 shows the changes in consumptions and in investments by goods in 2020 if a 5% growth of capital stock in electricity sector is assumed. All consumptions and investments would increase by almost all goods. Particularly, household consumption of electricity would increase the most, by 0.5% for both rural and urban households.

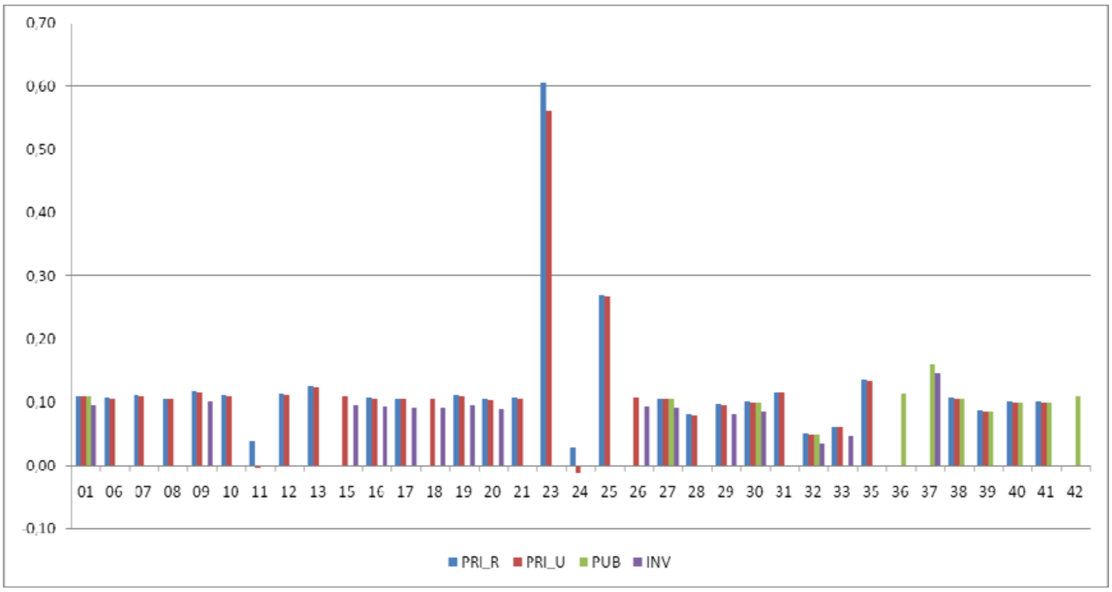

Figure 9. % changes in consumptions and investments by goods in 2020

Almost all the industries would benefit from the 5% increase in capital stock in electricity sector. Figure 10 shows changes in industrial value added in 2020 if the 5% increase in capital stock in electricity sector is assumed. The only two exceptions are the industry of metal smelting and pressing and electricity generation industry. Increase in capital stock in electricity sector would result in cheaper electricity supply in the market. This would stimulate the economy in Beijing. However, the decrease of electricity price in the market would also have the electricity sector suffer even though more electricity would be supplied.

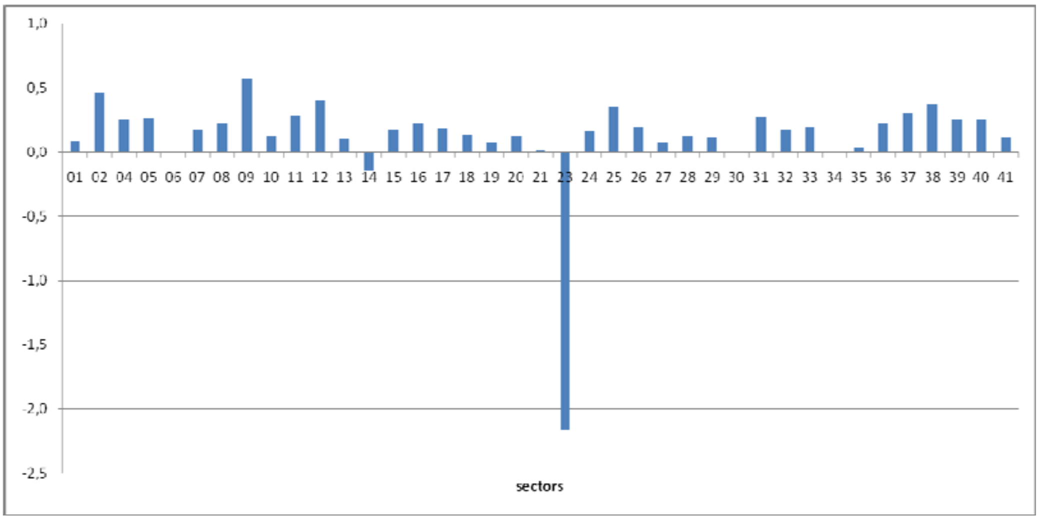

Figure 10. % changes in industrial value added in 2020

(2) Energy consumptions

The 5% increase in capital stock in electricity sector in Beijing would result in the increase in total energy consumption by way of decreasing in the energy prices pushed down by more electricity supply in the market. When compared with the reference scenario in 2020, total electricity consumption increases by 0.8%, coal by 0.3%, crude oil and refined oil by 0.2%, and natural gas by 0.1%.

Figure 11a shows % changes in electricity consumption by industries in 2020. All industries would consume more electricity if investment increases in electricity sector. This indicates that increase in investment in electricity sector would encourage more consumption of electricity. If the additional electricity supply stimulated by the investment policy is resulted from more investment in clean technologies, such as wind power, solar power, hydropower, and/or nuclear power, it is good for low carbon development because the economy would consume more clean energy – the electricity. However, if the additional electricity supply is resulted from fossil-fueled power plants, increasing demand for electricity would induce more consumption of "dirty" fossil fuels and hence likely result in more carbon emissions. Therefore, additional investment on electricity sector should be allocated to electric related technologies for renewable power generation so as to contribute to reduction in carbon emissions.

In this case we would have to separate renewable electricity technologies from fossil fueled electricity technologies in the model. Unfortunately, at this moment we haven't make such separation in the current model. Since only one aggregated electricity generation technology is considered in the current model, one by-effect of the additional investment in electricity sector would be that more fossil fuels consumption be induced because more electricity supply would lead to lower energy prices in the energy market. Cheaper energy stimulates more energy consumption.

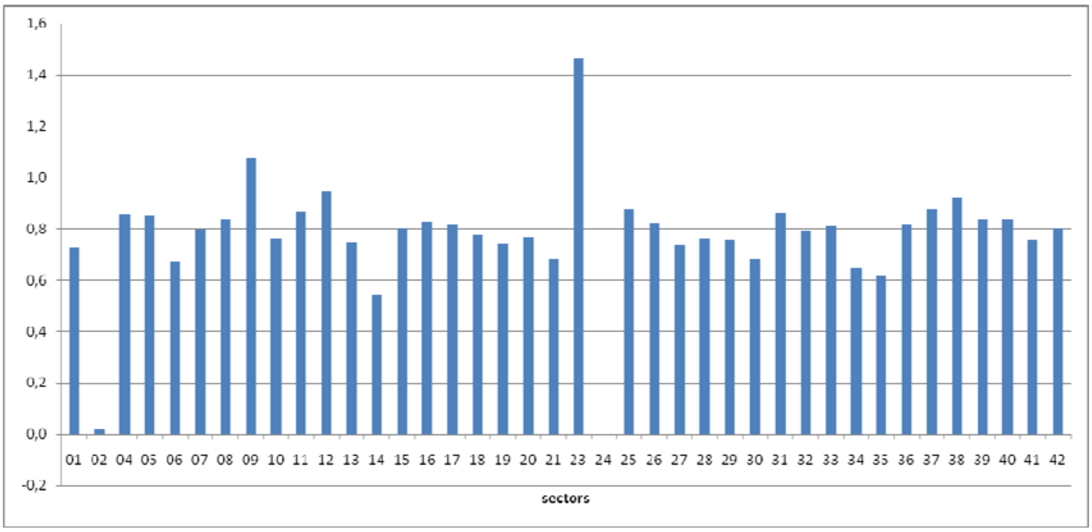

Figure 11a. % changes in electricity consumption by industries in 2020

Take the coal and refined oil consumptions as examples. Figure 11b shows % changes in coal consumption by industries in 2020, and Figure 11c shows % changes in refined oil consumption by industries in 2020, all of which result from the additional investment in electricity sector. Many industries tend to consume more coal and refined oil because in the current model the additional investment in the electricity sector is not restricted for only renewable power generation.

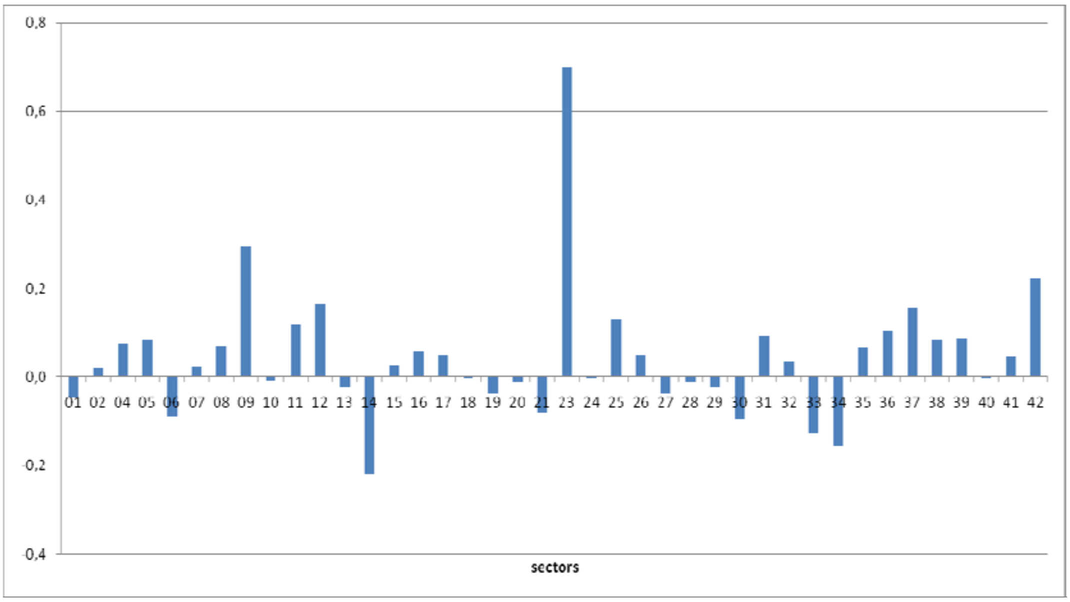

Figure 11b. % changes in coal consumption by industries in 2020

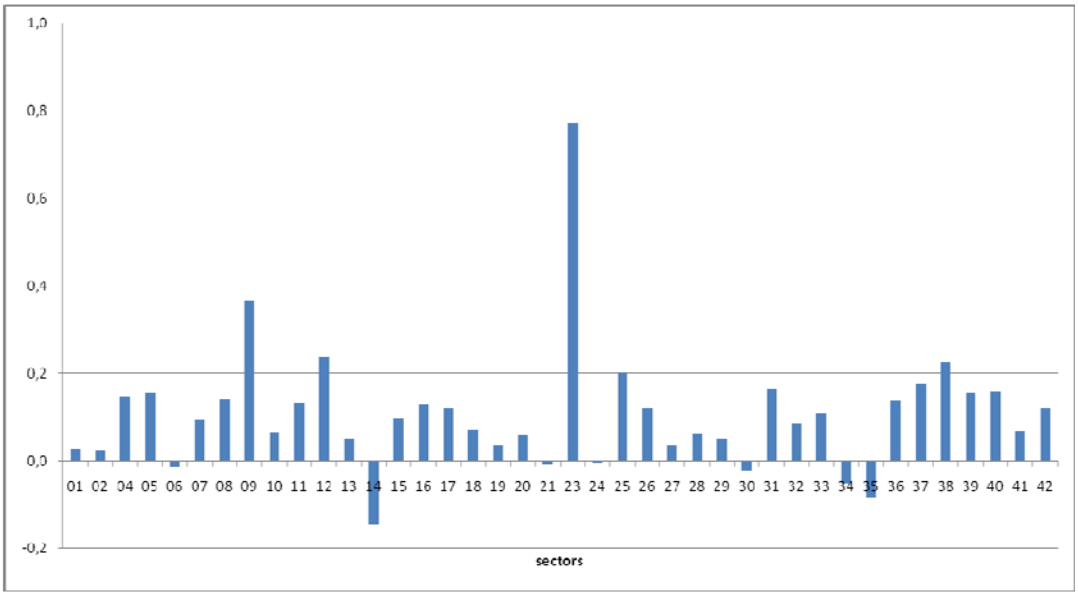

Figure 11c. % changes in refined oil consumption by industries in 2020

(3) Carbon emissions

IF the 5% increase in the capital stock in electricity sector is assumed in Beijing, total carbon emission in 2020 would increase by about 0.20%. At the sectoral level, shown in Figure 12, most of the 42 industries would have more carbon emissions. Only 6 industries would emit less carbon. At the aggregate level, the 5% increase in capital stock in electricity industry wouldn't contribute to reduction in carbon emission in Beijing. As indicated above, the additional investment in electricity industry is not particularly earmarked for renewable power generation in this simulation, which would result in the highest growth rate in carbon emission by the electricity industry as shown in Figure 12. However, if the additional investment is earmarked for renewable power generation, this result could be altered.

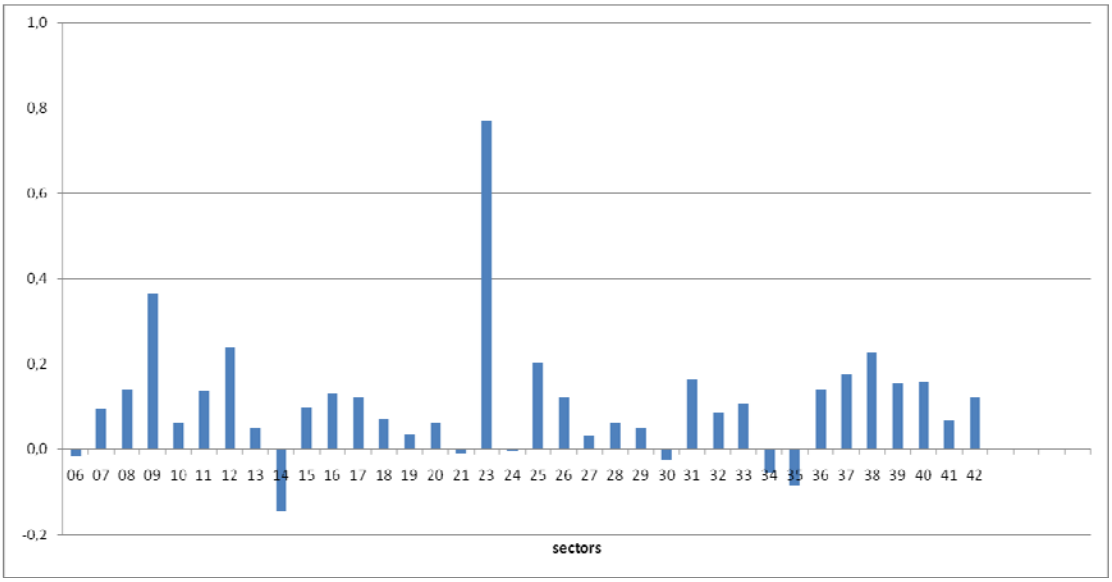

Figure 12. % changes in carbon emissions by industries in 2020

3.2.3 35 Yuan tax per ton of carbon emission

(1) Economic effects

If the carbon tax is levied at 35 Yuan tax (about 5 USD) per ton of carbon emission, the economy would be discouraged slightly and Beijing's GDP in both 2015 and 2020 would decline only by 0.015%, which could almost be ignored. In 2020, the consumptions of rural and urban households would decrease by only 0.05% and 0.005% respectively. The effects on government consumption and total investment in 2020 would be so trivial that they could be ignored. Figure 13 shows the % changes in consumptions and investments by industries if the carbon tax is levied at 5 USD tax per ton of carbon emission. Most of the goods would be consumed less than the reference scenario, in particular, the consumption of refined oil and natural gas would decrease the most because of the introduction of the carbon tax. However, the demand for electricity would increase because electricity is relatively "clean" with less carbon tax burden.

However, at the industry level, some industries would benefit while the other industries would lose in varying degrees. Figure 14 shows % changes in industrial value added in 2020. Industries of coal and natural gas production would be the two biggest losers because

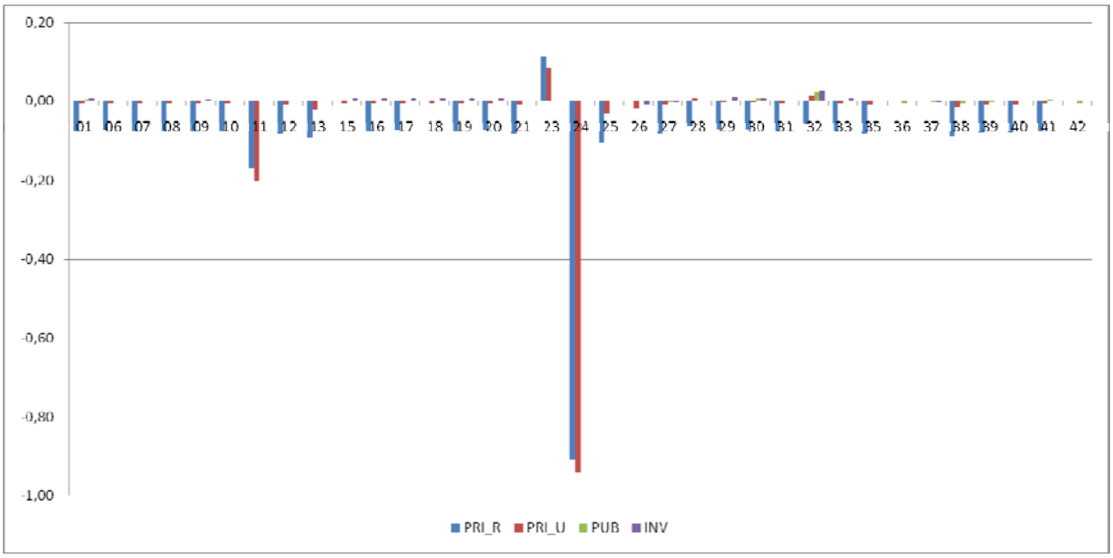

Figure 13. % changes in consumptions and investments by industries in 2020

the production of these two industries would be discouraged by less demand for "dirty" energy goods incurred by the introduction of the carbon tax. On the contrary, electricity industry would greatly benefit.

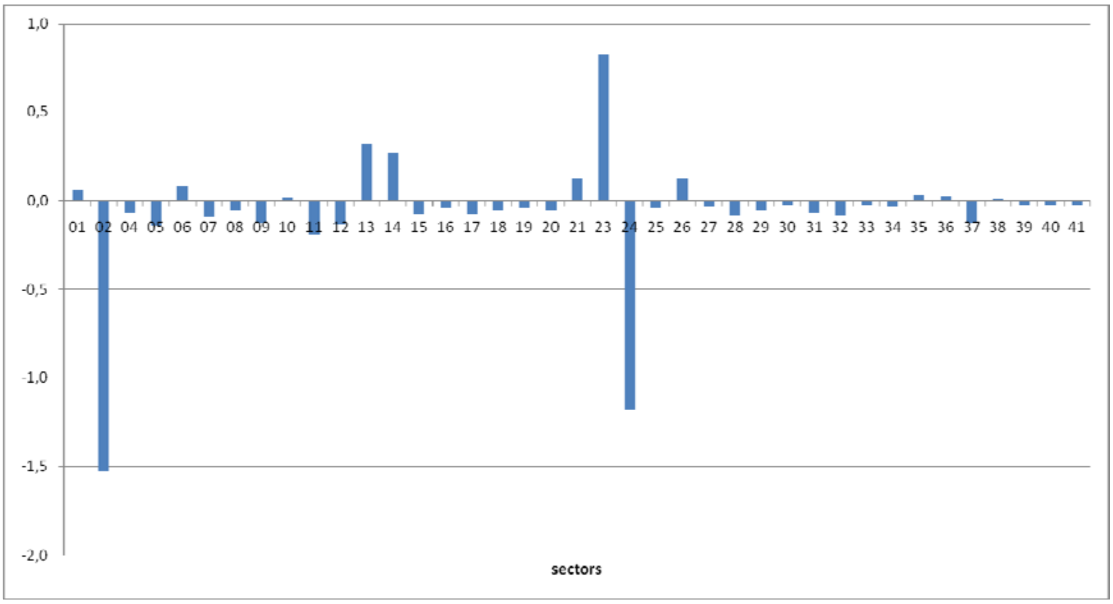

Figure 14. % changes in industrial value added in 2020

(2) Energy consumptions

The underlying mechanism for decrease in total energy consumption is that the prices of various energies would increase if the carbon tax is levied at 5 USD tax per ton of carbon emission, which implies that energy consumers have to pay more for consuming the same amount of energy. It is estimated that total coal and natural gas consumptions in 2020 would decline by 0.65% and 0.7% respectively, crude oil by 0.4%, refined oil by 0.3%, and electricity by 0.1%.

Figure 15a and Figure 15b show the % changes in coal consumption and refined oil consumption by industries in 2020 incurred by the introduction of the carbon tax. Most industries would consume less coal and less refined oil if the carbon tax is introduced, which indicates that carbon tax would contribute to reductions in consumption of coal and refined oil goods. This result is as expected because the carbon tax would increase the prices of coal and refined goods and hence decrease carbon emissions associated with the decreasing coal and refined oil consumptions.

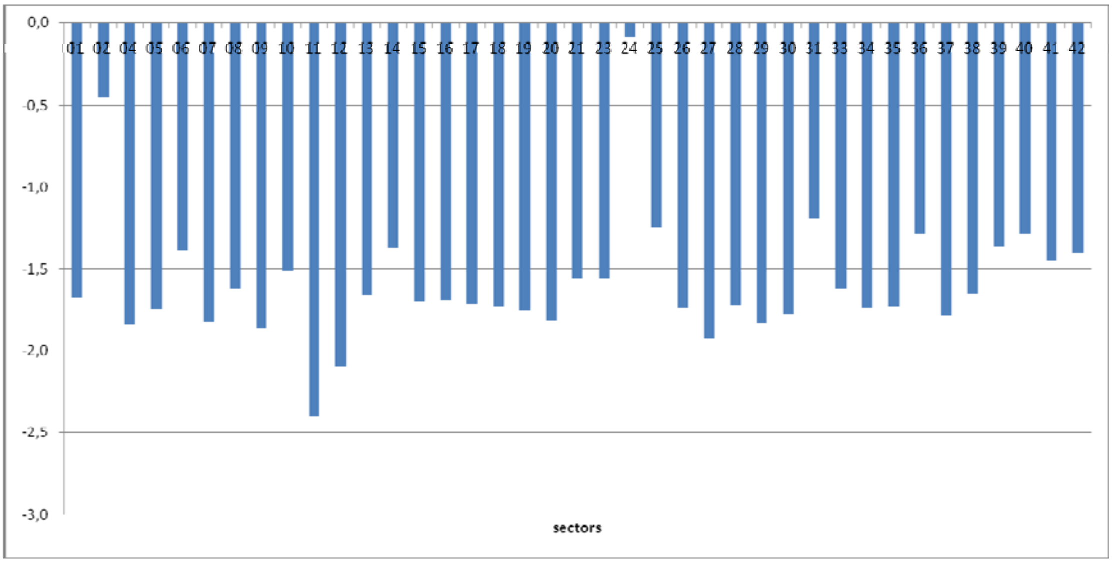

Figure 15a. % changes in coal consumption by industries in 2020

On the contrary, however, the carbon tax introduced would have much less negative effects on consumption of "clean" energy goods like electricity. Figure 15c shows % change in electricity consumption by industries in 2020. Most industries would consume slightly less electricity if the carbon tax is introduced when compared with the coal consumption case. Industries of coal and refined oil production would greatly reduce electricity consumption because the outputs of these two industries would be discouraged if the carbon tax is introduced. However, the metal smelting and pressing industry would consume even more electricity as shown in Figure 15c.

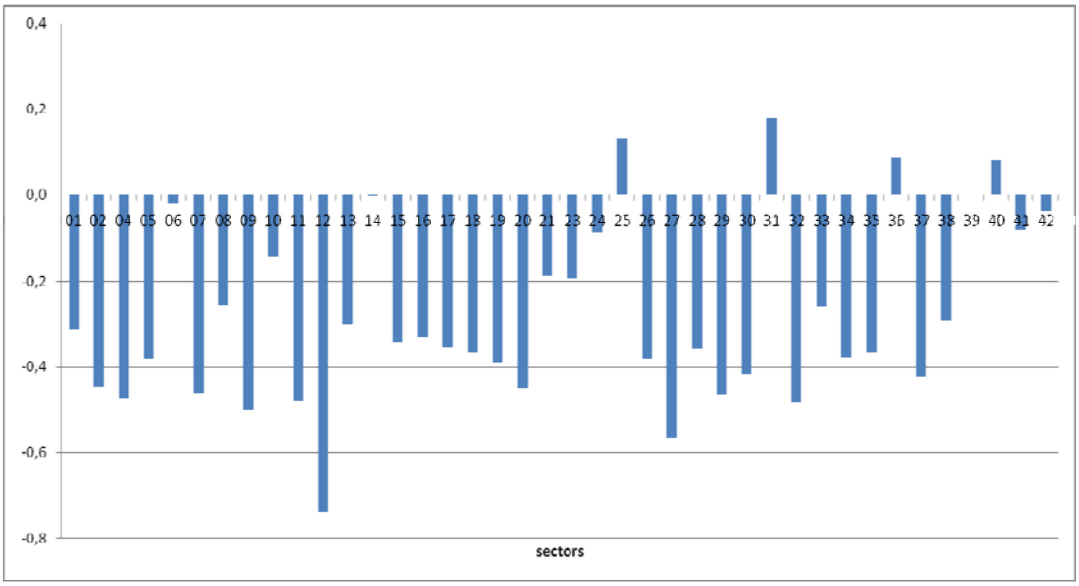

Figure 15b. % changes in refined oil consumption by industries in 2020

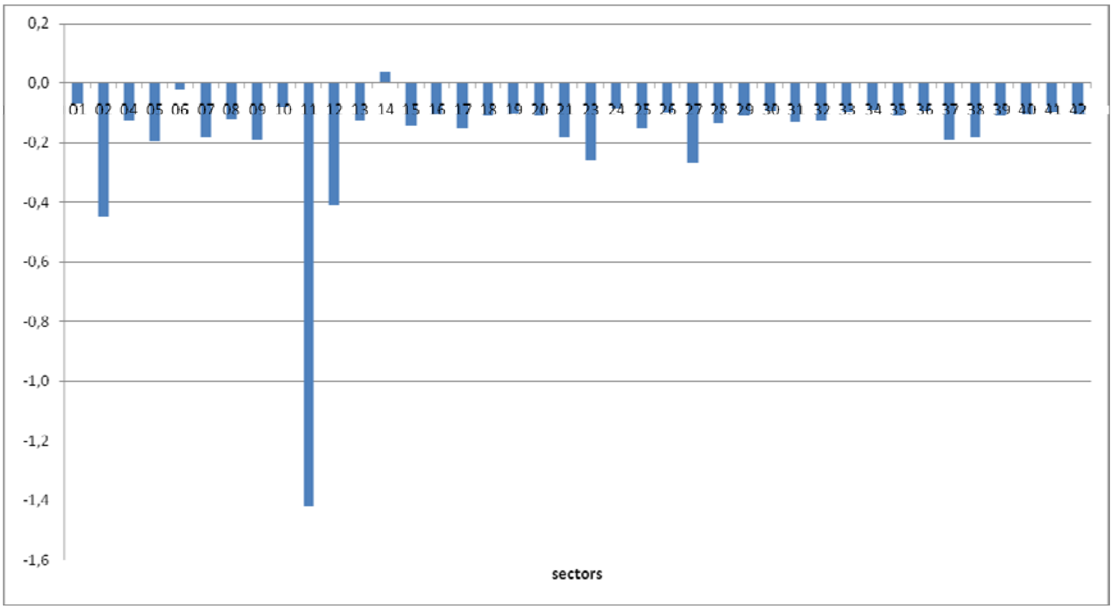

Figure 15c. % changes in electricity consumption by industries in 2020

(3) Carbon emissions

If the carbon tax is levied at 5 USD tax per ton of carbon emission in Beijing, total carbon emission in 2020 would reduce slightly by 0.9%. At industry level as shown in Figure 16, all industries would reduce carbon emissions because the levied carbon tax would increase the costs to use fossil fuels.

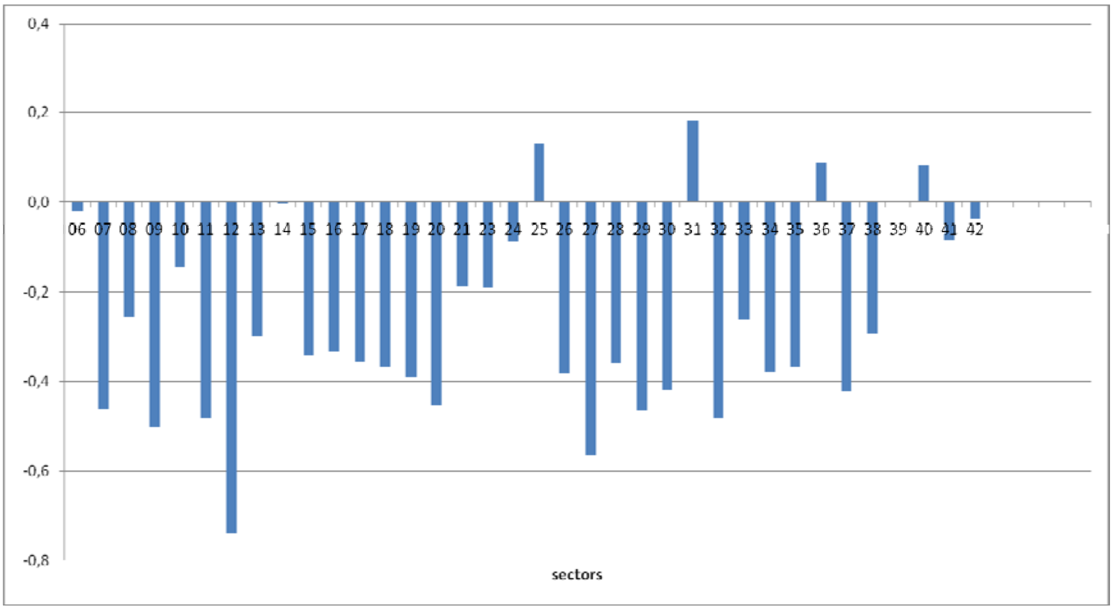

Figure 16. % changes in carbon emission by industries in 2020

3.3 Conclusions

The conclusions may be drawn based on the CGE modeling results.

(1) The improvement in energy efficiency would accelerate final consumption, capital formation and economic growth, and contribute to the reduction in carbon emission. The improvement in energy efficiency would have different effects on the energy production industries. The improvement in energy efficiency would result in the decrease of the local prices of energy goods in Beijing and the comparative increase of the prices of energy goods outside Beijing. As a result, the induced additional output of dirty energies such as coal and refined oil goods would have to flow out to other regions in China or export abroad because of the comparative advantage in costs incurred by the improvement in energy efficiency in these energy industries in Beijing. The different energy supply pattern in terms of the dependence on the outside economies would have different impacts on the local energy production by industry in Beijing.

(2) If more investment on power generation is allocated, the Beijing's final consumption, capital formation and economic growth would be accelerated and almost all industries would benefit from the policy incentives. However, the electricity generation industry would be affected by the combination of induced supply increase and price decrease. While the increase in electricity supply would result in more consumption of coal and refined oil, the comparative decrease in price of electricity would result in more consumption of electricity and hence more carbon emission.

(3)Carbon tax would contribute to encourage the consumption and production of clean energies such as electricity and constrain the consumption and production of dirty energies such as coal and refined oils, and hence have different impact on the economic growth by industry. Carbon tax would increase the cost of fuel fossil consumption and hence induce to the reduction in carbon emission.

In general in terms of carbon emission, both measures of the improvement of energy efficiency and the carbon tax would contribute to the reduction in carbon emission, and the measure on more investment allocated in electricity industry would result in the increase in carbon emission. At the industry level, the carbon tax instrument would contribute to reduction in carbon emission by each industry, while the measures of the improvement of energy efficiency and more investment allocated in electricity industry would contribute to the reductions in carbon emissions in some industries and result in the increases in carbon emissions in some other industries in varying degrees.

In general in terms of economic growth, the measures of the improvement of energy efficiency and more investment allocated in electricity industry would accelerate economic growth in Beijing, and the carbon tax would result in the decreasing in economic growth in Beijing. At the industry level, the carbon tax instrument would result in decrease in economic growth by each industry, while the measures of the improvement of energy efficiency and more investment allocated in electricity industry would contribute to the acceleration of economic growth in some industries and result in the decreases of economic growth in some other industries in varying degrees.

4. The composite effect of the carbon tax and related subsidy policy mix

To promote the low-carbon development of an economy, reducing energy consumption and carbon emission while fueling economic growth, different economic policies, measures and instruments may be adopted. In the third assessment report (Synthesis Report),IPCC (2001) divided these policies, measures and instruments into three categories, namely market based instruments, regulatory instruments and voluntary agreements. The market based instruments include carbon taxes / energy taxes, subsidies, emission taxes, trading schemes. It is believed that the market based policy tools, in particular domestic revenue and tradable emission permits system are more attractive to governments at different level, because governments have to take not just the cost effectiveness into consideration. However, just as pointed out by OECD (2009) in discussing the policy tools for climatic change mitigation in "*The Economics of Climatic Change Mitigation: Policies and Options for Global Action beyond 2012*", "*the way in which the revenues from the tax are recycled is important. In theory, the more revenues are used to reduce other taxes that have negative side effects on economic activity, the greater the cost effectiveness of the scheme. This is the so-called double-dividend of corrective taxes on pollution*". Generally speaking, carbon taxes / energy taxes and emission taxes may be conductive to the mitigation of carbon emissions; however, they may also bring about negative impact on economic development. Therefore, carbon taxes / energy taxes and emission taxes should be implemented in combination with the policy subsidies for energy saving and emission reduction, so as to keep revenue neutral. The underlying mechanism is that in addition to stimulating the favorable economic activities, the subsidies for energy saving and emission reduction would also reduce the costs associated with energy consumption and carbon emission. The carbon taxes and the subsidies for energy saving and emission reduction address different market imperfections and can have offsetting functions by combination for promoting low-carbon development in a cost effective way. Moreover, for China and Beijing in promoting low-carbon economy development, the policy combination of the subsidies for energy saving and emission reduction and the carbon tax would be more practical and effective in the context of cost effectiveness.

As required by the terms of reference, the Beijing CGE model for low-carbon development is updated to allow for the introduction of the subsidiary policy tools for energy conservation and emission reduction, so as to make counter-factural simulations in terms of the baseline projections and long-term effects of the subsidiary policies underlying in the "12th Five-year Plan" in Beijing. By dynamic simulations we would supplement the carbon tax analysis with subsidiary policy analysis and draw underlying conclusions for policy mix suggestions.

4.1 Policy Scenarios and Simulated Results

In order to promote low-carbon development and achieve the low-carbon strategic goals in 2020, Beijing needs to adopt various combinations of policies, measures and tools because different policy combinations would imply different effects. Hereinafter, we further analyze the combined effects of imposing carbon tax and utilizing the revenue from carbon tax as investment subsidies in electricity industry for energy conservation and emission reduction, taking into account of various combination scenarios of the two kinds of policy tools.

4.1.1 Policy Scenarios

For counter-factual policy analysis, the baseline scenario and three policy scenarios are assumed as follows.

Business as Usual scenario (BAU): It is assumed that additional 10% taxation is imposed on the use of coal products and petroleum products. This BAU scenario is mainly used as the reference for comparison.

Policy Scenario 1 (SN1): It is assumed that while additional 10% taxation is imposed on the use of coal products and petroleum products, 5% of the associated revenue would be used as an investment subsidy in electricity industry.

Policy Scenario 2 (SN2): It is assumed that while additional 10% taxation is imposed on the use of coal products and petroleum products, 10% of the associated revenue would be used as an investment subsidy in electricity industry.

Policy Scenario 3 (SN3): It is assumed that while additional 10% taxation is imposed on the use of coal products and petroleum products, 10% of the associated revenue would be used as an investment subsidy in electricity industry and clean coal industry.

We applied the updated dynamic CGE model for Beijing low-carbon development to simulate these scenarios. Although we have simulated the effects of different scenario mixes in the next 10 years, only the cumulative effects are provided hereinafter.

4.1.2 The results of simulated effects on industrial outputs

The effects of policy combinations on industrial outputs are simulated, which are respectively shown in Figure 17, Figure 18 and Figure 19.

Figure 17 presents the % changes in industrial outputs under scenario BAU and scenario SN1. The simulated results show that:

(1) In the BAU simulation, the additional 10% taxation rate imposed on the use of coal products and petroleum products would result in the total GDP of Beijing declining by 0.72%. At industry level, the coal mining and washing industry would suffer the most, with its output decreasing by 19.75%; the other industries that would obviously suffer include: the processing industry of petroleum, coking and nuclear fuel, the manufacturing industry of nonmetallic mineral products, the mining and processing industry of nonmetal ores and other ores, the smelting and rolling industry of metals, the industry for traffic, transport and storage, the chemical industry, the production and supply industry of electricity and heat power, and the agriculture industry. However, the industries that would gain include: the industry of research and experimental development, the industry of information transmission, computer services and software, the leasing and business services, the industry of public management and social organization, and the industry of culture, sports and entertainment.

(2) In the SN1 simulation, the combination of the 10% taxation rate imposed on the use of coal products and petroleum products and the 5% investment subsidy in electricity industry would offset, and make Beijing’s real GDP decrease less by 0.02% compared with the BAU result. It implies that the 5% investment subsidy policy would mitigate the negative impact on industrial outputs incurred from the 10% taxation imposed on use of coal and petroleum products. This kind of offsetting function is applied to all industries but not the industry of public management and social organization, the industry of health, social security and social welfare, the industry of research and experimental development, and education industry. Moreover, the offsetting effect resulted from the 5% investment subsidy in the electricity industry is not significantly remarkable, which would merely mitigate the GDP decrease rate in the construction industry by 0.07%, the best one at industry level.

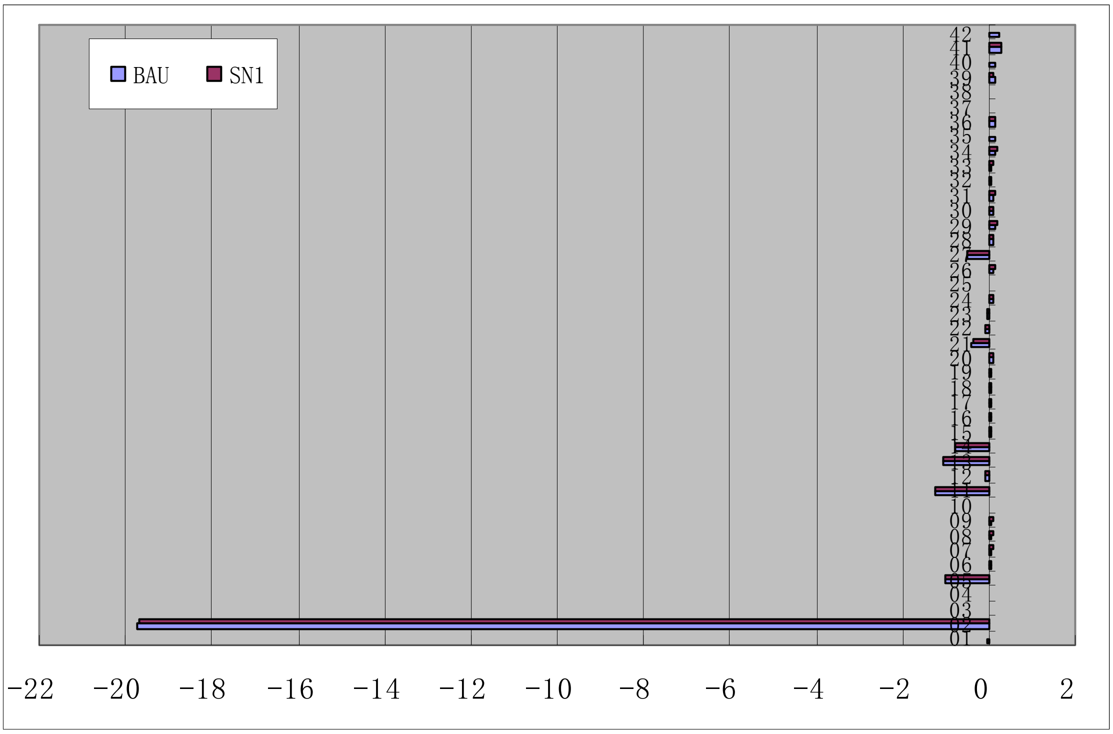

Figure 17. % changes in industrial outputs under BAU and SN1 scenarios

Figure 18 presents the % changes in industrial outputs under scenario BAU and scenario SN2. The simulated results show that in the SN2 simulation, the increase of investment subsidy from 5% to 10% in electricity industry, combining with the 10% taxation rate imposed on the use of coal products and petroleum products, would contribute to improve the results in SN1 scenario, resulting in offsetting the actual GDP decrease rate by 0.045%; however, this offsetting function would not be remarkable enough to reverse the pattern under the scenario SN1. At industry level, the offsetting effect resulted from the increase of investment subsidy from 5% to 10% in electricity industry, combining with the effect from the 10% taxation rate imposed on the use of coal products and petroleum products, would just mitigate the GDP decrease rate in the construction industry by 0.144% in scenario SN2 compared with 0.07% in scenario SN1, the best result at industry level.

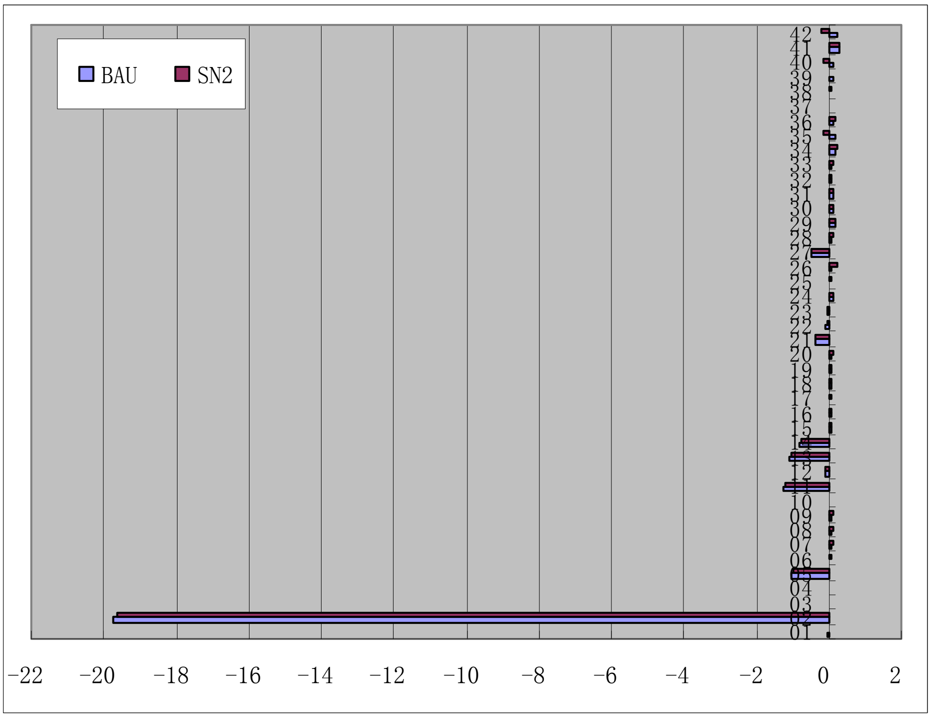

Figure 18. % changes in industrial outputs under the BAU and SN2 scenarios

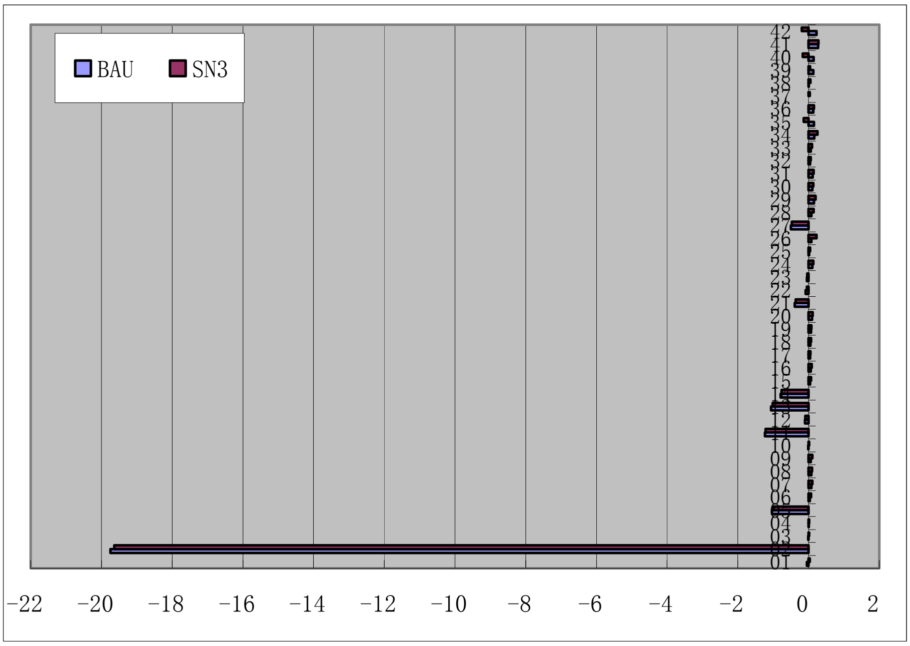

Figure 19. % changes in industrial outputs under the BAU and SN3 scenarios

Figure 19 presents the % changes in industrial outputs under scenario BAU and scenario SN3. The simulated results show that in the SN3 simulation, the joint increases of investment subsidy from 5% to 10% in electricity industry and of the coal-saving investment subsidy rate by 10%, combining with the 10% taxation rate imposed on the use of coal products and petroleum products, would further contribute to improve the results in SN1 scenario, resulting in offsetting the actual GDP decrease rate by 0.046%; however, this offsetting function would not be remarkable enough to reverse the pattern under the scenario SN1. At industry level, the offsetting effect resulted from the joint increases of investment subsidy from 5% to 10% in electricity industry and of the coal-saving investment subsidy rate by 10%, combining with the effect from the 10% taxation rate imposed on the use of coal products and petroleum products, would just mitigate the GDP decrease rate in the construction industry by 0.145% in scenario SN3 compared with 0.07% in scenario SN1, the best result at industry level.

4.2 Basic Conclusions and Policy Implications

Given the current status of low-carbon development in Beijing, China's National Climate Change Programme and the strategy of low-carbon development in China, Beijing is required to put forward its strategic goals for low-carbon development during 2010-2020, and its practical policies, measures and tools to promote the low-carbon development in Beijing. The experiences in low-carbon development both abroad and home as well as the relevant policy options demonstrate that, in order to implement the low-carbon development strategy during the period from 2010 to 2020, Beijing needs to make optimal combination for comprehensive choices according to the environmental effectiveness, cost effectiveness, administrative and political feasibility of possible policies, measures and tools.

To implement low-carbon development strategy, several market based policy tools, including carbon taxes, policy subsidies for energy conservation and emission reduction, investment and technologies for improving energy efficiency, are alternative for Beijing. By using Beijing CGE model, we made quantitative simulations and counter-factural analysis on the effects of different combination scenarios of these policy tools on economic growth, energy consumptions and carbon emissions. The simulated results show that, the carbon tax policy tools can effectively restrain energy consumption and carbon emission, but would lower the economic growth rate and raise genuine national income distribution concerns. The subsidy policy tools for energy conservation and emission reduction can effectively stimulate the activities of energy conservation and emission reduction and economic growth, provide offsetting function to the carbon tax tools, but need the supports of financial resources. The practice of improving energy efficiency can promote energy conservation and emission reduction, but requires technical conditions and financial resources to offset the high costs.

As most of the counter-factural analysis based on numerical models for economic analysis on mitigation of climatic change pointed out, the simulated results and underlying mechanisms imply that, the policies and measures for the implementation of low-carbon development strategy in Beijing should be made based on the integrated application of applicable policies, measures and tools. Only by integrated planning and application of the applicable policies, measures and tools for promoting low-carbon development, it would be possible to improve the overall effect and performance in the implementation of low-carbon development strategy and policies and achieve Beijing's strategic goals of low-carbon development by the year 2020.

Appendix 1：The industries in the Beijing SAM

	42 Sector	53 Sector
1	Agriculture	Agriculture
2	Mining and washing of coal	Mining and washing of coal
3	Extraction of Petroleum and Natrual Gas	Extraction of Petroleum and Natrual Gas
4	Mining of Metal Ores	Mining of Metal Ores
5	Mining of Non-Ferrous Metal Ores	Mining of Non-Ferrous Metal Ores
6	Manufacture of foods and Tobacco	Manufacture of foods and Tobacco
7	Manufacture of Textile	Manufacture of Textile
8	Manufacture of Textile Wearing Apparel,Footwear and Caps	Manufacture of Textile Wearing Apparel,Footwear and Caps
9	Processing of Timbers, Manufacture of Furniture	Processing of Timbers, Manufacture of Furniture
10	Papermaking,Printing and Manufacture of Articles for Culture, Education and Sports Activities	Papermaking,Printing and Manufacture of Articles for Culture, Education and Sports Activities
11	Processing of Petroleum, Coking, Processing of Nuclear Fuel	Processing of Petroleum
		Desiel
		Fuel oil
		Liquefied Natural Gas
		Coking
12	Chemical Industry	Chemical Industry
13	Manufacture of Nonmetallic Mineral Products	Manufacture of Nonmetallic Mineral Products
14	Smelting and Rolling of Metals	Smelting and Rolling of Metals
15	Manufacture of Metal Products	Manufacture of Metal Products
16	Manufacture of General Purpose and Special Purpose Machinery	Manufacture of General Purpose and Special Purpose Machinery

17	Manufacture of Transport Equipment	Manufacture of Transport Equipment
18	Manufacture of Elecrical Machinery and Equipment	Manufacture of Elecrical Machinery and Equipment
19	Manufacture of Communication Equipment, Computer and Other Eletronic Equibment	Manufacture of Communication Equipment, Computer and Other Eletronic Equibment
20	Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work	Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work
21	Other Manufacture	Other Manufacture
22	Scrap and Waste	Scrap and Waste
23	Production and Supply of Electricity and Heat Power	Production and Supply of Electricity and Heat Power
24	Production and Distribution of Gas	Production and Distribution of Gas
25	Production and Distribution of Water	Production and Distribution of Water
26	Construction	Construction
27	Traffic, Transport and Storage	Transport Via Railway
		Transport Via Road
		Urban Public Traffic
		Water Transport
		Air Transport
		Transport Via Pipeline
		Loading, Unloading, Portage and Other Transport Services
		Storage
28	Post	Post
29	Information Transmission, Computer Services and Software	Information Transmission, Computer Services and Software
30	Wholesale and Retail Trades	Wholesale and Retail Trades
31	Hotels and Catering Services	Hotels and Catering Services
32	Financial Intermediation	Financial Intermediation

33	Real Estate	Real Estate
34	Leasing and Business Services	Leasing and Business Services
35	Research and Experimental Development	Research and Experimental Development
36	Comprehensive Technical Services	Comprehensive Technical Services
37	Management of Water Conservancy, Environment and Public Facilities	Management of Water Conservancy, Environment and Public Facilities
38	Services to Households and Other Services	Services to Households and Other Services
39	Education	Education
40	Health， Social Security and Social Welfare	Health， Social Security and Social Welfare
41	Culture, Sports and Entertainment	Culture, Sports and Entertainment
42	Public Management and Social Organization	Public Management and Social Organization

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