The Heavy Industries under Economy Slowdown and Emission Trading Schemes in China

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Part A. Assessment of influence of economic slowdown in China

A.1. Background

China has been growing at an unprecedented rate since economic reforms were initiated in 1978. However, China's strong growth streak recently has run out of steam, showing a steady and marked deceleration since around 2012. China's real GDP dropped from an average of 10.76% over the period 2003-2011 to 7.2% between 2012 and 2017 (State Statistical Bureau, 2018). In 2014, the Chinese President Xi Jinping applied the term "New Normal" to China's slowing growth. The slowdown has naturally drawn worldwide concerns as China has been acting as the largest engine of global growth for many years.

GDP data by industry suggest that China's secondary industries, especially the heavy industries have exhibited a more marked growth slowdown—from over 10% during 2008 and

2011 to 6.0% in 2015. The heavy industry includes all industries that produce production materials and provides material and technical base for the national economy. According to the National Bureau of Statistics, heavy industry accounts for over 70% of the total industry. To better understand China's recent slowdown, this report analyzes the impact of economy slowdown on heavy industries by using a state-level general equilibrium model for China.

The remainder of the report is structured as the following: Section 2 provides details about the performance of economic slowdown in China; Section 3 describes the model and new Excess Capacity module; Section 4 present the stimulation and results; And lastly, Section 5 concludes.

A.2. Performance of economic slowdown in China

In this sector, we will analysis the data of gross domestic product (GDP) growth, investment growth, export growth and consumption growth, make a contrast of growth trend of GDP with those of investment, export, and consumption, try to find out the performance of economic slowdown in China from expenditure side.

For this report, we use data on GDP for the years 1979-2016, consumption for the years 1979-2016, and investment for the years 1979-2016. The data are taken from Chinese State Statistics Bureau.

A.2.1. GDP

GDP growth: Figure 1 shows the GDP growth of China in RMB from 1979 to 2016. After Reform and Opening in 1978, the GDP growth in China was not huge from 1979 to about 1990, and despite the GDP growth rate may be quite significant. The GDP growth in China has begun to take off from around 1990. While the GDP growth started to decrease from around 1995 with growth value 1271.6 billion RMB. From 1995 to 2000, Chinese economy experience a short-term slowdown. In 2002, China joined the World Trade Organization (WTO) and Chinese economy restrike its engines. The GDP growth raised dramatically to 5049.2 billion RMB before the global financial crisis in 2008. In response to the crisis, central government introduced the "four-trillion" investment fiscal policy and the GDP growth raise again after the fall in the short term. Since the GDP growth reaching a peak of 7533 billion RMB around 2012, the GDP growth in China have been slowing steadily till now.

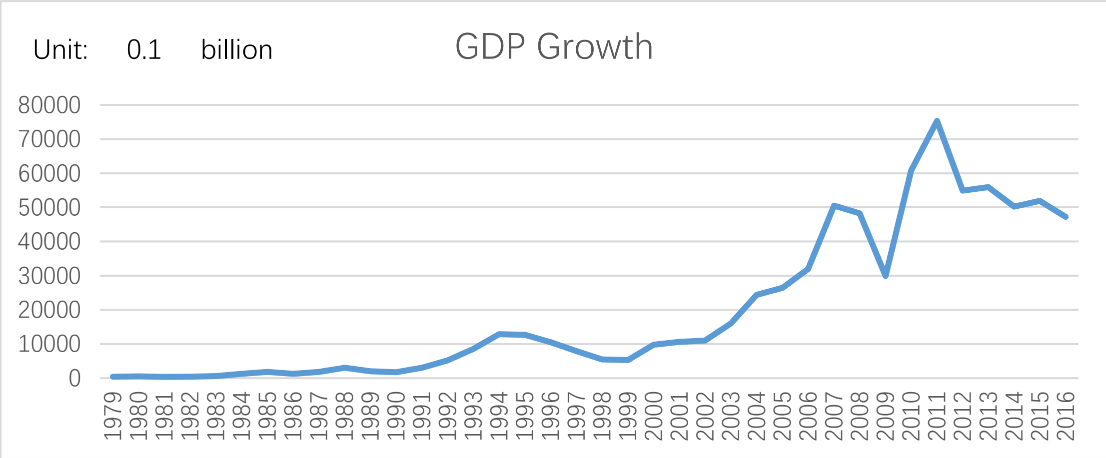

Figure 1. GDP growth of China from 1979 to 2016

A.2.2. Investment

Investment growth: Figure 2 shows the investment growth of China in RMB from 1979 to 2016. The investment growth coincided well with the GDP growth; and they both begun to boom around 1990 and experienced the first slowdown between 1995 and 2000. From 2001 to 2008, the investment growth had raised dramatically with some fluctuations to 2619.6 billion RMB. After the global financial crisis in 2008, the investment growth experienced a temporary drop and then raised again to 3667.4 billion RMB in 2011. Then the investment growth has decreased in a fluctuation way.

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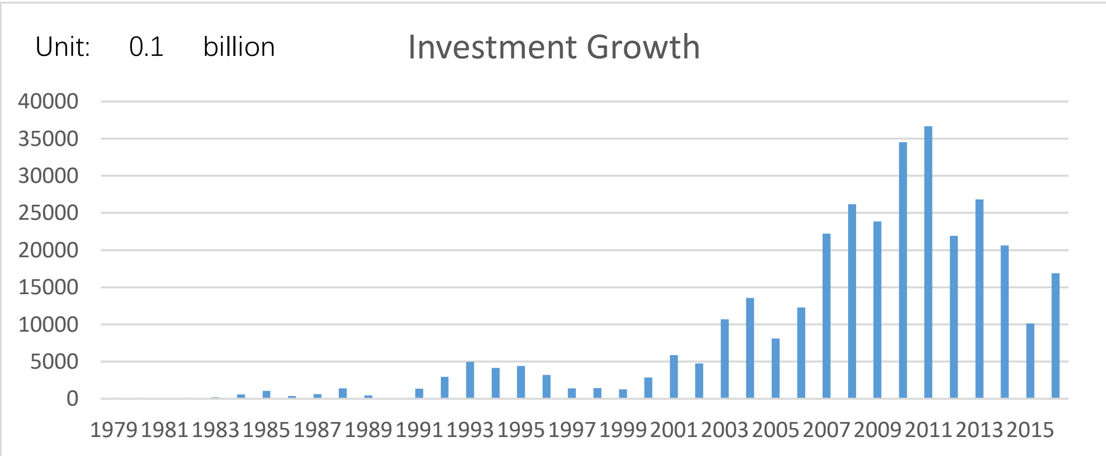

Figure 2. Investment growth of China from 1979 to 2016

A.2.3. Export

Net export growth: Figure 3 shows the net export growth of China in RMB from 1979 to

2016.

The trend of the net export growth in China was not pronounced before 2002. We start seeing some major change in net export growth from 1993 but the changes are uncertain. For instants, the net export growth in 1993 and 1999 was significantly negative while the net export growth increased markedly in 1994 and 1997. After 2002, the net export growth trend began to converge with the GDP growth. The net export growth raised significantly to 676.8 billion RMB between 2002 and 2008. After the global financial crisis in 2008, the net export growth fluctuate due to the global demand decreased and the outbreak of trade war, with a downward trend in overall until today.

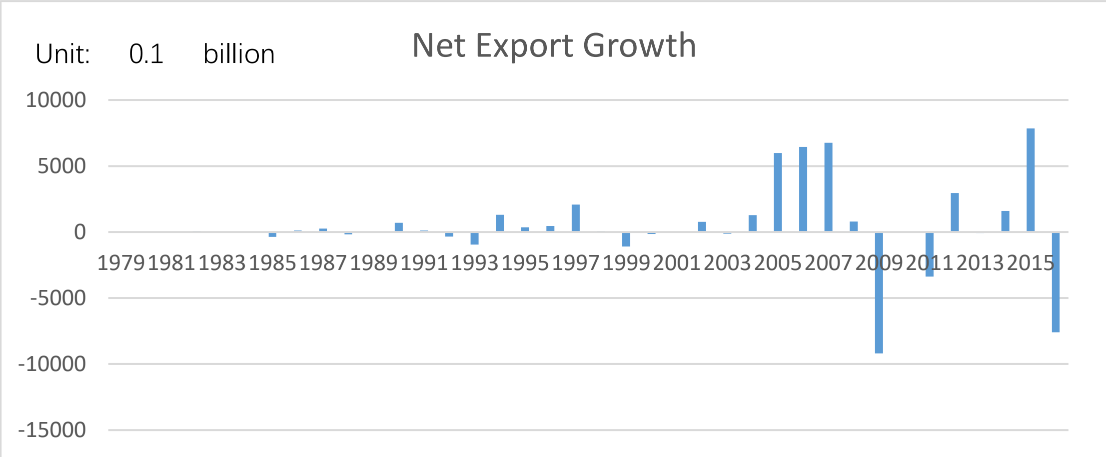

Figure 3. Net export growth of China from 1979 to 2016

A.2.4. Consumption

Consumption growth: Figure 4 shows the consumption growth of China in RMB from 1979 to 2016. Before 1990, the consumption growth was unremarkable. Afterwards the consumption growth increased rapidly until peaked with growth value 792.6 billion RMB in 1995. From 1995 to 2000, the consumption growth reduced the speed. Except a short-term stabilization between 2001 and 2003 and a temporary drop in 2009, the consumption growth experienced a new long term up trend until 2011. In general, between 1979 and 2011, the trend of consumption growth in China is almost the same as the GDP growth. However, after the Chinese economy began a renewed slowdown from around 2002, the consumption growth entered a stable period, with slight rise.

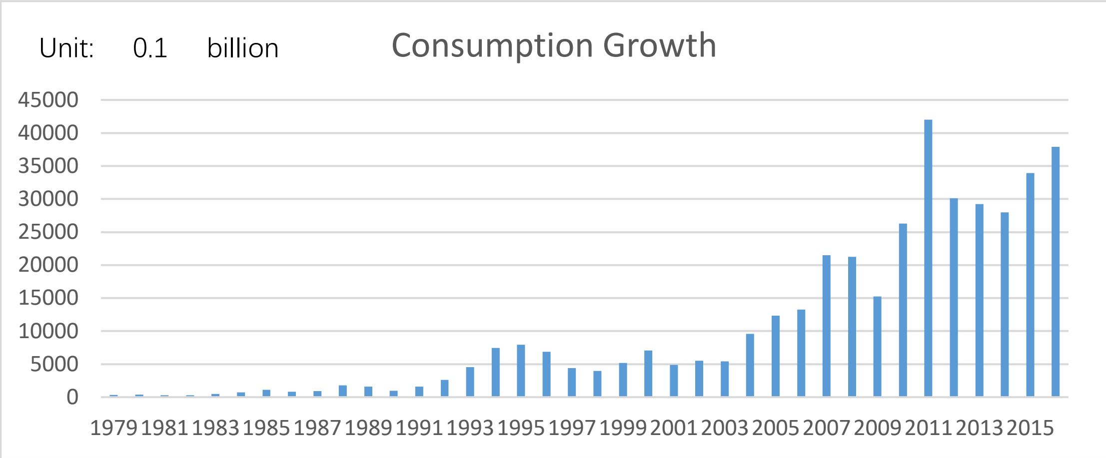

Figure 4. Consumption growth of China from 1979 to 2016

A.3. Model and Excess Capacity module

A.3.1. CGE Model

This study adopts a state-level general equilibrium model for China, named CHINAGEM. CHINAGEM was developed from the MONASH model – a recursive dynamic CGE model of the Australian economy. Since the 1990s, the MONASH model has had rich applied experience in economic policy analysis on a broad range of issues such as trade reform; tax reform; forecasting greenhouse gas emissions; forecasting regional employment by detailed occupations; population aging and related issues. In the past decade, the MONASH model has become a platform for developing dynamic CGE models for other economies. The Chinese version of MONASH-style dynamic model is CHINAGEM.

CHINAGEM simulations start from a base year for which a detailed input-output table is available. The input-output table is used to construct a model database that portrait a picture of the Chinese economy for that year. The model database provides an initial solution for the CHINAGEM equation system. The CHINAGEM equation system has a quantity and a price variable corresponding to every value in the input-output database. A CHINAGEM simulation moves each of the components of the input-output database, thereby taking us to another picture of the economy.

In order to estimate the economic slowdown of China, this paper makes further improvements for CHINAGEM model. Firstly, the model database has been updated. The original model adopts the 2007 National Input–Output Tables, however, due to the economic development and changes of industrial structures, this database cannot satisfactorily meet the needs of evaluating economic slowdown which started from 2012. Therefore, we update the central database comprehensively by using the 2012 National Input–Output Tables of China published recently by National Bureau of Statistics. Secondly, the Excess Capacity module is added. CGE models commonly use production functions with labor and materials treated as variable inputs. By contrast, capital is treated as fixed in the short run, with the level of capital input determined by past investments. The treatment of capital rests on the assumption of continuous full-capacity utilization. However, based on our observation, we find that it is not possible to stimulate the main features of economy slowdown with this assumption. This means that we need to drop the standard full-capacity utilization assumption and allow excess capacity.

A.3.2. Excess Capacity module

Reductions in capacity utilization is one of the main features for slowdown and recessions. Even when capital can be substituted for other factors, leaving capital stock idle is a rational response to slowdown or recession because fixed costs exist for keeping plants open. In allowing for excess capacity, we introduced sticky adjustment in rental rates. Under stick adjustment, rather than viewing rental rates as prices that adjust instantaneously to clear the market for the services of the existing capital stock, we viewed rental rates as adjusting sluggishly implying that in a downturn some of the existing capital stock is left unemployed.

Specificallly, we introduced a distinction in CHINAGEM between capital in use in industry j for year t $[KU(j,t)]$ and capital in existence in industry j for year t $[KE(j,t)]$. During slowdown period, we allow capital in use in each industry to fall below capital in existence. The sticky rental adjustment mechanism is applied via the following equations:

$$\left\{\frac{Q(j,t)}{Q_b(j,t)}-1\right\}=\left\{\frac{Q(j,t-1)}{Q_b(j,t-1)}-1\right\}+\alpha_2\left\{\frac{KU(j,t)}{KE(j,t)}-1\right\}+S(j,t)\ for\ all\ t \quad (1)$$

$$\mathrm{Q}(j,t)=n_j(KU(j,t),\cdots)\ for\ all\ t \quad (2)$$

$$S(j,t)=0 \text{ for t} < t_c(j) \quad (3)$$

$$S(j,t)\geq 0 \text{ for t} = t_c(j) \quad (4)$$

$$KU(j,t)=KE(j,t)\ for\ t\geq t_c(j) \quad (5)$$

$$KU(j,t)\leq KE(j,t)\ for\ t \quad (6)$$

In the equations, $Q(j,t)$ and $Q_b(j,t)$ are the rental rates in industry j for year t in perturbation and baseline runs, $S(j,t)$ is a slack variable used for complementarity. α_2 is a positive parameter and $t_c(j)$ is the year in which industry j regains full-capacity utilization. Therefore, we assume that full capacity is maintained beyond $t_c(j)$. Equation (1) shows the sticky rental adjustment specification and equation (2) is the capital demand equation derived from the condition that the rental on capital is the value of the marginal product of capital in use.

A.4. Simulation and Results

This study will simulate the economic and environmental impacts of economy slowdown on heavy industries from 2013 to 2022. As mentioned in Section A.2, during the present slowdown period from around 2012, the net export growth and investment growth decrease with the GDP decrease, while the consumption growth stays stable with slight rise. As a result, in the report, the policy shocks are set by the following:

1. Add an investment confidence variable to the investment equation and the investment confidence will decrease by -17% over the whole stimulation period. The numerical value equals to the investment growth rate from 2002 to 2011 minus the investment growth rate from 2012 to 2017.
2. The export growth will decrease by -15% over the whole stimulation period. The numerical value equals to the export growth rate from 2002 to 2011 minus the export growth rate from 2012 to 2017.

In this paper, we employ CHINAGEM model to simulate economic and environmental influence of the whole economy slowdown from around 2012, especially the influence on heavy industries. The macroeconomic impacts are shown in Table 2. According to the model results, most of the macroeconomic indicators would decrease due to deceased investment and export compared to no-slowdown scenario. The economy slowdown will bring down GDP growth by 5.27% in 2022, which is worth 66.8 billion RMB. From the expenditure side of GDP, not only investment (investment confidence) and export demand will decline during the slowdown period, we also noticed that, the consumption would also decrease with value 55.5 billion RMB in 2022 due to lower employment rate and real wage.

Decreased investment and net export reduce output of most industries and decreasing output lead to reduced labor force employment and reduced real wage. Table 2 demonstrates that economy slowdown results in 8.59% decline in employment rate and 1.48% decline in real wage in 2022. More than 711 million people will be affected. Declined employment rate and declined real wage further lead to income and household consumption decreasing, which will renew the negative impact on GDP. Nevertheless, the good news is economy slowdown can also reduce the carbon emission of China. Specifically, the carbon emission of China will dropped by 8.17% in 2022 with value 1329 million tons.

Table 2. Macroeconomic Impact of economy slowdown

Variable	Macro variation in 2022 compared to baseline (percentage)	Baseline Data in 2022 (100 million RMB)	Macro variation in 2022 compared to baseline (100 million RMB)
Carbon Emission	-8.17	1329	-116

		million tons	million tons
GDP	-5.27	1268145	-66831
Employment	-8.89	800350 thousand people	-71151
Consumption	-10.19	544737	-55509
Foreign import	-5.83	255996	-14925
Capital used	-3.14	368302	-11564
Rate of Capital Return	-4.35	-	-
Capital Price	-0.0096	-	-
CPI	-1.51	-	-
Real Wage	-1.48	-	-
Export price	-0.41	-	-

Data source: the macro variation percentage were gathered from CHINAGEM Model simulation results.

In terms of price level, economy slowdown will push consumer price index (CPI) to decrease by 1.51% in 2022 compared to no-slowdown scenario. The results also show the price of outcome for most industries declined and stay low for the whole slowdown period. However, capital price declined slightly by 0.96% in 2022, which is much lower than expectation. This is mainly because the new excess capacity mechanism allows producers to shut down the unprofitable plants, which cushion the impact of excess capacity and avoid quick decline of capital price.

In terms of international trade, exports decline by 15% (exogenous), and imports decrease by 5.85% in 2022. The absolute falling value of the later is much more than the former. From the model results, decline of foreign export is exogenous due to global economy crisis and trade war. While the falling imports is primarily because of shrinking industrial outcomes and consumption.

Table 3. Impact of economy slowdown on Industrial Output and Prices

Industry	**Output (%)**	**Price (%)**	**Employment (%)**	**Capital used (%)**	**Capital created (%)**
Coal	-6.95	-2.70	-8.70	-2.46	-6.57
Crude Oil	-2.16	-2.12	-3.68	0.45	-2.44
Crude Gas	-5.42	-2.45	-8.41	-2.16	-6.37
Basic Chemistry	-7.16	-1.03	-8.47	-2.29	-6.46
Plastic	-8.28	-0.65	-8.21	-2.78	-6.98
Glass	-6.72	-1.30	-7.55	-2.46	-5.68
Iron and Steel	-7.34	-1.66	-8.51	-3.02	-6.43

Machinery Manufacturing	-6.52	-1.09	-7.25	-2.40	-5.40
Automobile	-8.26	-1.20	-9.34	-3.54	-7.23
Shipbuilding	-6.87	-1.02	-7.36	-2.81	-5.51
Construction	-8.73	-1.11	-9.29	-3.82	-7.15

Data source: CHINAGEM simulation results

Table 3 depicts the impacts of slowdown on heavy industries' output, prices, employment and capital use in 2022. Heavy industries are always capital-intensive and export-oriented, so they are more vulnerable to decreased investment and export. Therefore, we can expect heavy industries share similar trend with the macro-economy's performance. The results do show heavy industries like Plastic, Glass, Iron and Steel, Machinery Manufacturing, Automobile, Shipbuilding and Construction are negatively affected on output and price in 2022. Among them, the most negatively affected industries are Automobile (-8.26%) and Construction (-8.73%). Similarly, the employment in Automobile (-9.34%) and Construction (-9.25%) will also experience the biggest drop in 2022. It is noteworthy that the employment lost in heavy industries is more serious than the output lost. The main reason is capital will substitute for labor gradually compared to on-slowdown scenario due to the excess capacity in these industries.

Meanwhile, the price of energy industries like Coal, Crude Oil and Crude Gas are most negatively affected under slowdown. In 2022, the price of Coal industry will decrease by 2.70%, the price of Crude oil will decrease by 2.12%, and the price of Crude gas will decrease by 2.45%. We found it is because market demand in energy industries fall faster than other heavy industries, as most heavy industries are energy-intensive and demand decrease in all these industries will push down the demand of Coal, Crude Oil and Crude Gas.

Regarding capital use, the new excess capacity mechanism introduced two distinct indictors for capital in use and capital in existence. One industry can cut off excess capital by deciding only use a part of capital in existence. Besides, the industry will create less and less investment year by year until excess capacity disappear. For instants, from the start year of slowdown (assumed in 2014), the Crude Oil industry decided only to use a part of capital in existence and decreased the investment in next year. However, from Table 3, we can see in 2022 the variation in the capital in use and the capital in existence are still not equal, indicating none of the heavy industries can adjust the excess capacity in a short term.

A.5. Conclusions

This study constructs a General Equilibrium Model (CGE) with the excess capacity mechanism, establishes scenarios based on declined investment and export during the economy slowdown period and simulates the slowdown impacts on heavy industries in China. We found that:

(1) Decreased investment and export lower most of macroeconomic terms including employment rate, real wage, CPI and consumption. The good news is carbon emission will drop (-5.27%), too. The capital price will remain stable due to excess capacity mechanism as the excess capacity mechanism allow the producers to use partial existing capital.
(2) The heavy industries like Plastic, Glass, Iron and Steel, Machinery Manufacturing, Automobile, Shipbuilding and Construction are negatively affected on output and price during the slowdown period. In addition, unemployment in these industries would be more seriously affected because of the substitution from capital.
(3) Meanwhile, the price of energy industries like Coal, Crude Oil, and Crude Gas are most negatively affected with sharply decreased energy demand.
(4) Though heavy industries can cut off excess capital by deciding only use partial existing capital, most of the heavy industries cannot self-adjust the excess capacity in a short term.

Our study shows that the economy slowdown would be a big challenge for China's future development. Declined investment and export will also drag down the domestic consumption demand. As a result, it is not easy to transfer the economy into consumption-driven style under slowdown scenario.

The industry-level results show most of heavy industries are negatively affected. By contrast, energy industries including Coal, Crude Oil and Crude Gas are most negatively affected on price. Therefore, it is hard to develop clean energy when energy price is lower.

The industry-level results also indicate heavy industries can adjust their excess capacity but the self-adjustment takes quit a long period. As a result, there is a need for the policy of industrial structure adjustment from the government, but the self-adjustment should be taken into account in the policy design.

Part B. Assessment of impacts of Emission Trading Schemes in China

B.1. Background

Climate change has been a challenge confronted by all human beings of contemporary society. China has been more actively involved in controlling greenhouse gas (GHG) emission and building its ability to adapt to climate change gradually. In 2009, China pledged to reduce its carbon dioxide emissions per unit of GDP by 40% to 45% by 2020 compared to the level of 2005. In 2015, China announced its enhanced actions and measures on climate change in a document entitled *Enhanced Actions on Climate Change,* which proposed a number of voluntary goals: carbon dioxide emissions would peak in 2030; carbon dioxide emissions per unit of GDP would decline by 60% to 65% compared with the level of 2005.

Recognizing the high costs of command and control measures during the 11th Five Year Plan
(2006–2010), China has increasingly focused on market-based measures such as emission trading schemes (ETS) to achieve this target. In theory, ETS allows more flexibility on where GHG emissions are to be reduced and creates a continuous incentive for improvement. As a result, emission cuts can be achieved at least cost by trading between high and low marginal cost emitters. In practice, the Clean Development Mechanism (CDM) has increased the familiarity of Chinese government with ETS and has simultaneously established several key elements of ETS in China. Therefore, China is attempting to establish ETS step by step to explore a new mode of low-carbon development.

As a first step, China announced to launch seven Pilot ETSs in two provinces (Hubei and Guangdong) and five cities (Beijing, Shanghai, Shenzhen, Tianjin and Chongqing) in 2011. The Pilot ETSs are intended to gain experience associated with implementation of ETS and to identify challenges that should be resolved before moving to a nationwide ETS. During the pilot phase, local governments have the flexibility to design their ETSs according to local circumstances. By the end of 2014, these seven Pilot ETSs have been operated cumulatively. The seven Pilot ETSs cover 18% of China's population, and 30% of its national GDP. It is estimated that these Pilot ETSs could eventually regulate between 0.8 and 1.0 billion tons of carbon dioxide emissions, and become the second largest ETS after EU ETS in terms of allowance scale.

Later on, China began preparing to establish a nationwide ETS, which is expected to come into a mature phase from 2017 to 2020. Once China's national carbon market is established, China will overtake the EU ETS to become the largest carbon market in the world. China's experience and lessons with Pilot ETSs.

Therefore, it is necessary to make a quantitative estimation for Pilot ETSs, especially their economic and environmental effects, which will provide a basis for scientific decisions on establishing a nationwide ETS.

The remainder of the report is structured as the following: Section 2 provides details about the state of Carbon ETS in China; Section 3 describes the model and new Carbon ETS module; Section 4 present the stimulation and results; And lastly, Section 5 concludes.

B.2. The state of Carbon ETS in China

In Shenzhen

ETS in Shenzhen is the first Pilot ETS in China. By the end of 2018, the Pilot ETS has controlled cumulatively 28.42 million tons of carbon dioxide emissions, and the turnover had been 0.876 billion RMB. So far, the Pilot ETS in Shenzhen has involved 811 enterprises with emission in 11 different industries. In 2014, foreign investors were allowed in the ETS in Shenzhen.

In Shanghai

ETS in Shanghai was established in 2013. So far, the ETS has involved 310 enterprises with heavy emission in 27 different industries, including Steel, Electricity, Chemical Industry, Building Materials, Textile, Aviation, Water Transportation, and Commercial Hotel. By the end of 2018, the Pilot ETS has controlled cumulatively 87.41 million tons of carbon dioxide emissions, and the turnover had been 0.9 billion RMB. In 2018, the carbon emissions from enterprises declined by approximately 7% compared to the emission in 2013.

In Beijing

ETS in Beijing was also established in 2013. The business volume has accumulated to approximately 20 million tons and valued 1.45 billion RMB. In 2016, the ETS in Beijing changed its inclusion criteria from 10 thousand tons' emission per year to 5 thousand per year, then the number of enterprises involved in ETS doubled.

In Guangdong

ETS in Guangdong was established in 2013. The business volume has accumulated to approximately 58.10 million tons and valued 1.42 billion RMB. Enterprises that are involved in ETS are distributed in Electricity, Cement, Steel, Petrochemical, Paper Making and Civil Aviation.

In Tianjin

ETS in Guangdong was established at the end of 2013. The ETS included 114 enterprises that discharge more than 20 thousand tons' carbon dioxide per year and these enterprises are distributed in Iron and Steel, Chemical Industry, Electric Power Thermal, Petrochemical, and Mining.

In Hubei

ETS in Hubei was opened in 2014. The Pilot ETS in Hubei has involved 236 enterprises, 6306 individuals and foreign investors. All the enterprises in ETS consume more than 60 thousand tons of criterion coal every year. Every year, the quotas in Hubei ETS will be liquidated and redistributed.

In Chongqing

ETS in Chongqing was opened in 2014. The carbon market have begun active since 2017. By the end of 2018, the cumulative transaction has been more than 8 million tons of carbon dioxide emissions. Meanwhile, the enterprises have been concentrated in energy-intensive industries including electrolytic aluminum, ferroalloy, calcium carbide, caustic soda, cement and steel.

B.3. Model and Carbon ETS module

B.3.1. CGE Model

This study adopts the Chinese multi-regional general equilibrium model (termCO2), which was constructed jointly by Institute of Policy and Management, Chinese Academy of Science (IPM, CAS) and Center of Policy Studies, Victoria University is used.

TermCO2 has a bottom-up structure which treats each region of the country as an individual ‘‘economy” and links regional economic activities through trading, investment and labor movement. It permits inter-regional re-exports, which is different from other bottom-up models. In other words, the direct imports of a province are not necessarily used in this province since it may be exported to other provinces. Similarly, exports from a province are not necessarily produced there, and they may come from other provinces. TermCO2 stands out from Top-Down models, as it not only can analyze impacts resulting from demand side in one region, but also can simulate the influence resulting from supply side in that region.

In order to estimate the economic and environmental impacts of Hubei Pilot ETS, this paper makes further improvements for TermCO2 model. Firstly, the model database has been updated. The original model adopts the 2002 Provincial Input–Output Tables, however, due to the economic development and changes of industrial structures, this database cannot satisfactorily meet the needs of actual research work. Therefore, we update the central database comprehensively and systematically by using the 2007 Provincial Input–Output Tables of China published recently by National Bureau of Statistics. Secondly, the carbon ETS module is added. Usually, typical energy and environmental models only contain substitution in energy production and carbon emission account, thus only effects of carbon tax or changes of emission cap can be simulated. Unlike such models, carbon ETS module is added in our model to analyze the influence of carbon trading market.

B.3.2. Carbon ETS module

In TermCo2 model, carbon emissions come from combustion of various fossil fuels. The industrial emissions *(E)* is calculated as $E_i=\sum n\ (X_{ni}\times\alpha_{ni}\times O_{ni})$, where *X* refers to consumption of fossil fuels, α refers to emission coefficient, and *O* refers to oxidation rate, *i* indicates industry i, and *n* indicates energy n. Costs generated by carbon ETS are added to energy cost, in other words, industry i's energy input *(C)* includes energy costs, $X_{ni}\times Pe_n$, as well as corresponding costs generated by carbon emission, E_i*P.

$$C_i=\sum n(X_{ni}\times Pe_n+E_i\times P) \quad (1)$$

In order to deal with rising energy cost generated by carbon ETS, TermCo2 model hypothesizes that there are three emission reduction mechanisms in short term: energy substitution (substituting cleaner energy, like gas for coal), factor substitution (using lower-cost factor combinations by substitutions between capital, labor and energy), output reduction (rising production cost leads to decrease in consumption and profit, thus resulting in decline of output indirectly). Based on the hypotheses above, CGE model can simulate marginal abatement cost (MAC)curves of single economic sector or the whole economy, and obtain the quantity of carbon reduction under carbon tax and equilibrium carbon price of carbon ETS to further evaluate the economic and environmental influence.

The MAC curves in CGE model can be illustrated from two angels: carbon tax and carbon ETS. If carbon tax (T) in a given level is introduced as an exogenous variable, CGE model will determine endogenously the carbon emission level (E) after the shock. As shown in Figure 1(a), the quantity of carbon emission can be obtained through simulation of carbon tax, and thus the MAC curve can be generated. The reverse process can simulate the impacts of carbon ETS. TermCo2 model introduces a cap of carbon emission (Q) to get the shadow prices of carbon allowance (P). The shadow price is equal to carbon tax when carbon emission is equal to the cap, and it is also carbon allowance price due to carbon ETS in a given area and time period. As illustrated in Figure 1(b), carbon MAC curve can also be obtained by simulating carbon cap. The stricter the cap is limited, the higher MAC and corresponding allowance prices.

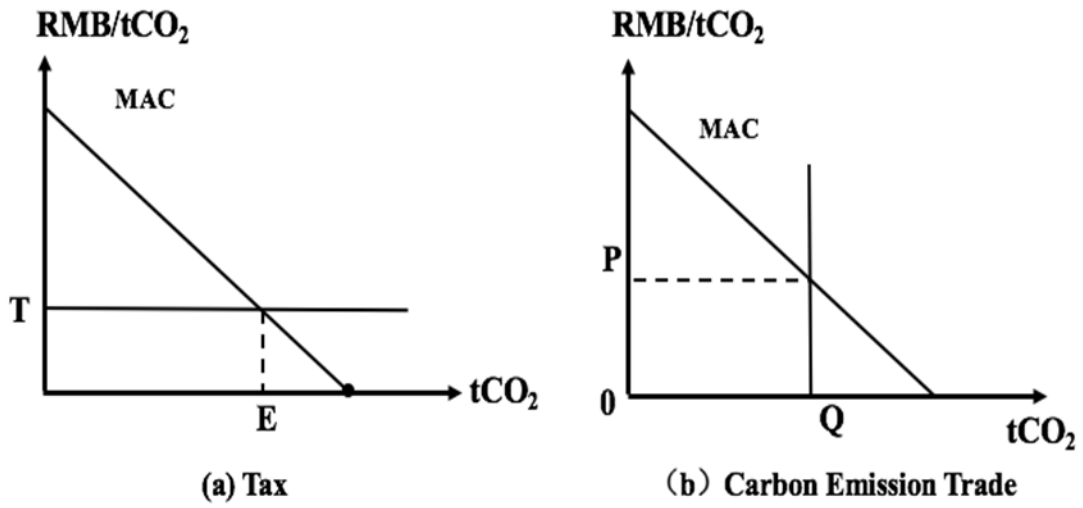

Figure 1. The MAC curves in CGE model

Carbon ETS usually covers several industries, and different industries have different number of free allowances. Moreover, because of disparity of carbon emission structures and reduction potential, MAC curves are different among industries, thus, MAC varies in different industries regardless of carbon trading market. As shown in Figure 2, suppose that Industry 1 and Industry 2 have allowance Q_1 and Q_2 respectively; TermCo2 model can simulate the MAC curves of these two industries. When allowance trading is absent, MACs of Industry 1 and Industry 2 are P_1 and P_2 respectively. After the establishment of carbon trading market, there would be allowance trading (ΔQ) between Industry 1 and Industry 2 until the allowance price (P) is equal to their MAC. Therefore, TermCo2 model can simulate the carbon ETS's shock of various industries, and take into account the interactions between industries, thus obtaining a MAC curve synthesized by all covering industries. [1]

Equilibrium carbon price can be formulated as follows:

$$min\sum_i C_i=\sum_i[\sum_n(X_{ni}\times Pe_n+E_i\times P)] \qquad (2)$$

$$s.t.\sum_i Q_i=\sum_i E_i$$

where ΔQ_1 is industry 1 sales allowances ΔQ_1, ΔQ_2 is industry 2 purchases allowances, and $\Delta Q_1=\Delta Q_2$. On this basis, the model can figure out carbon ETS' impacts on macroeconomics, carbon emission, and industrial output, etc.

B.4. Simulation and Results

B.4.1. Simulation

In April, 2014, Hubei province issued the *Interim Regulations on Carbon Emission Trading in Hubei Province*. The key institutional factors are as follows:

[1] Considering interaction between industries, composite MAC curves does not mean simple horizontal summation of different industrial MAC curves.

1. Coverage: Enterprises whose energy consumption is more than 60,000tons of coal in either 2010 or 2011 are covered by the Pilot ETS. After being confirmed, 138 enterprises in 10 industries, covering 35.81% of the provincial carbon emission in 2011,are claimed to meet the standard.
2. Cap: The cap is dependent upon development of Hubei's economy, target of carbon mitigation, structural adjustments, and technical progress, etc., and the following year's cap is adjusted according to the preceding year's economy and carbon emission. The cap in 2014 is324 million tons.
3. Allowance allocation: There are three main types of allocation method: free allowance, government reserve and new entrant reserve. Free allowance accounts for around 70% of total amount of allowance, mainly used for existing facilities. Government reserve accounts for 8% of the total, primarily used to maintain stability of carbon trading market. 30% of government reserve can be used for public auction. New entrant reserve constituting 22% of the total is reserved for increase of production capacity and output.
4. Free allocation: Enterprises' free allowance is 97% of historical emission level. For Non-electrical enterprises, annual free allowances are allocated according to the above standard. For electrical enterprises, 50% of annual free allowances are calculated by the above standard, and the rest are determined by benchmark methodology (actual emission multiplied by benchmark line).
5. Ex-post adjustment mechanism: After verification, if the difference between the actual emission and the free allowance surpasses 20% or a 200,000 tons threshold, the government will supplement or recycle the allowances beyond the threshold. Extra emissions will be covered by the new entrant reserve.

This study will simulate the economic and environmental impacts of Hubei Pilot ETS in 2014. The scenarios would keep consistent with institutional factors as much as possible, to achieve this, the policy shocks are set by the following steps:

(1) Percentage of covered enterprises in each industry *(a)*.Since 138 enterprises are distributed in ten industries, it will overestimate the impact if assuming the ten industries will all be involved in carbon ETS. Since TermCo2 model's simulation of effects of carbon ETS is based on the change of energy cost, this research uses percentage of covered enterprises' comprehensive energy consumption in each industry to determine *(a)*.

(2) The free allowance proportion of covered enterprises *(b)*. In Hubei Pilot ETS, government reserve and new entrant reserve are given out only in certain circumstances, and the ex-post adjustment mechanism is also quite strict, as a result, allowance limitation that cap covered enterprises face is initial free allowance. Non-electrical enterprises' free allowance is 97% of the historical level, while electrical enterprises' free allowance consists of two parts: historical part and benchmark part, which are almost equivalent in reality. Therefore, this study sets free allowance of electrical enterprises the same with non-electrical ones.

(3) The reduction rate of the covered industries' allowance*(c)*. The reduction rate of the 10 covered industries' allowance is the policy shock of Hubei Pilot ETS. It can be obtained by calculating *(a)* and *(b)*, and the formulation is $c=a\times(1-b)$. The results are shown in Table 1.

Table1.The Reduction Rate of the Covered Industry Allowance

Covered Industries	**Percentage of Covered Enterprises in Each Industry (*a*)**	**The Free Allowance Proportion of Covered Enterprises (*b*)**	**The Reduction Rate of the Covered Industry Allowance (*c*)**
Extraction of Petroleum and Natural Gas	52.72%	97.00%	1.58%
Manufacture of Foods and Tobacco	19.39%	97.00%	0.58%
Papermaking, Printing and Manufacture of Stationary and Sports Goods	16.74%	97.00%	0.50%
Processing of Petroleum, Coking, Processing of Nuclear Fuel	33.56%	97.00%	1.01%
Chemical Industry	54.37%	97.00%	1.63%
Mining and Processing of Nonmetal Ores and Other Ores	66.14%	97.00%	1.98%
Smelting and Rolling of Metals	66.06%	97.00%	1.98%
Manufacture of General Purpose and Special Purpose Machinery	25.69%	97.00%	0.77%
Manufacture of Transport Equipment	21.49%	97.00%	0.64%
Production and Supply of Electric Power and Heat Power	56.07%	97.00%	1.68%
Sum	**35.08%***	**97.00%**	**1.05%**

Note: *this percentage indicates the share of all the covered enterprises among the total energy consumption in Hubei province.

B.4.2. Results

This paper employs TermCo2 model to simulate economic and environmental influence of Hubei Pilot ETS in 2014. The macroeconomic impacts are shown in Table 2. According to the scenario, carbon ETS brings down the Hubei province's carbon emission by 1.00%, about 6.98 million tons of carbon dioxide (CO_2). In the same time, equilibrium carbon price is 34.31 yuan per ton, which means MAC is 34.31 yuan when the emission mitigation target is achieved. Results also show that, Hubei Pilot ETS will reduce GDP by 0.06% only in 2014, around 1.48 billion yuan. The reason of GDP decline is that carbon ETS reduces the output of covered industries, most of which are capital intensive. Capital stocks are unable to adapt to it in a short period of time, thus decreasing output lead to reduced labor force employment, and consequently causing a negative impact on GDP. We can draw conclusion from the simulation results that under present circumstance of Hubei Pilot ETS, elasticity of GDP to carbon reduction is 0.06, in other words, 1% emission reduction will cause 0.06% decline of GDP. In terms of absolute value, the average loss of Hubei's GDP is approximate 212.09 yuan/ton.

Table 2. Macroeconomic Impact of Hubei Pilot ETS in 2014

	Macro variation in 2014 (percentage)	**Data in 2013 (100 million RMB)**	**Macro variation in 2014 (100 million RMB)**
Carbon Emission	-1.00	697.83 million tons	6.98 million tons
GDP	-0.06	24668	-14.80
Employment	-0.09	36,920 thousand people	-33.2 thousand people
Consumption	0.35	10886	38.10
Investment	-0.33	20754	-68.49
Rate of Capital Return	-0.57	-	-
CPI	0.02	-	-
Foreign export	-0.07	1414	-0.99
Domestic outflow	-0.18		-
Foreign import	-0.11	839	-0.92
Domestic Inflow	-0.09		-
Export price	0.02		-

Data source: the macro variation percentage were gathered from TermCo2 simulation results, carbon emission in 2013 year was calculated through *energy year book*, while the rest data was collected from *Hubei Statistical Year Book in 2014* where original export and import was priced by US dollar, which was converted into RMB with the exchange rate: 6.1932.

Table 2 demonstrates that Hubei Pilot ETS results in about 0.09% decline in employment rate, which further leads to decreased income and household consumption, approximately affecting 33.2 thousand people. However, the model illustrates that household consumption of Hubei province raises by 0.35%, around3.81 billion yuan. This is mainly because the initial allowance given to enterprises is free, which is equivalent to offering subsidy to enterprise owners, thus stimulating expansion of household consumption directly. It embodies income distribution effect of carbon ETS. The results also show that provincial investment in Hubei decreases by 0.33% in 2014, approximate 6.849 billion yuan. The reason is that capital stock remains unchanged in the short run, and decreasing employment rate results in more abundant capital than labor force. In addition, the rate of capital return reduces by 0.57%, which causes decline of investment demand.

In terms of price level, Hubei Pilot ETS pushes consumer price index (CPI) to increase by 0.02% in 2014. This is mainly attributed by the rise of price in the following industries: Real Estate (0.18%), Chemical Industry (0.14%), Production and Supply of Electric Power and Heat Power (0.11%), Hotels and Catering Services (0.05%) and Manufacture of Foods and Tobacco (0.04%) (see Figure 3). These five industries together account for a large proportion of household consumption (45%), especially Manufacture of Foods and Tobacco (30%). As a result, Hubei's CPI becomes higher due to rising prices of related commodities. Among these industries, Manufacture of Foods and Tobacco, Chemical Industry, Production and Supply of Electric Power and Heat Power are covered by Pilot ETS, which increases energy cost and pushes up the prices of commodities (Cost Push). Real Estate and Hotels and Catering Services are expanded by the augment of household consumption demand, pulling up industrial output prices (Demand Pull).In terms of trading of Hubei, both international and domestic trade reveals a certain degree of shrinkage with different concrete manifestations. In terms of international trade, exports decline by 0.07% (-99 million yuan), and imports decrease by 0.11% (-92 million yuan). The absolute falling value of the former is more than the latter. However, the domestic trade appears an opposite trend. Domestic outflow decreases by 0.18% while domestic inflow drops by 0.09%. Decline of foreign export and domestic outflow is due to the rising CPI of Hubei (0.02%). The falling rate of domestic outflow exceeds it of foreign export is primarily because the competition between provinces is fiercer than that in global trade. Decrease of foreign import and domestic inflow is mainly caused by shrinkage of investment demand and declining GDP. The downward rate of foreign import is higher than domestic inflow as increase of Hubei's CPI stimulates domestic inflow from other provinces.

Table 3 depicts the Hubei Pilot ETS's impacts on industrial output and prices. It shows that Hubei Pilot ETS has a negative but relatively limited influence on industrial output, with changes less than 1%. Specifically, 37 of 42 industries are affected negatively, and simple average influence is -0.12%. By contrast, five of 42 industries benefit from the Pilot ETS, with 0.03% of simple average effect. The most negatively affected five industries are Nonmetal Ores (-0.86%), Smelting and Rolling of Metals (-0.66%), Chemical Industry (-0.56%), Production and Supply of Electric Power and Heat Power (-0.54%) and Construction (-0.21%). The former four are covered industries of ETS. Five beneficiaries are Manufacture of Leather, Fur, Feather Products (0.07%), Hotels and Catering Services (0.02%), Real Estate (0.02%), Education (0.02%) and Health Security and Social Welfare (0.02%), and all of them are not covered industries.

Table 3. Impact of Hubei Pilot ETS on Industrial Output and Prices

Covered industry	**Output (%)**	**Price (%)**	**Covered industry**	**Output (%)**	**Price (%)**
Extraction of Petroleum and Natural Gas	-0.03	-0.01	Nonmetal Minerals Industry	-0.86	0.25
Manufacture of Foods and Tobacco	-0.02	0.04	Smelting and Rolling of Metals	-0.66	0.14
Papermaking, Printing and Manufacture of Stationary and Sports Goods	-0.13	0.04	Manufacture of General Purpose and Special Purpose Machinery	-0.18	0.01
Chemical Industry	-0.56	0.14	Manufacture of Transport Equipment	-0.11	0.01
Processing of Petroleum, Coking, Processing of Nuclear Fuel	-0.13	-0.03	Production and Supply of Electric Power and Heat Power	-0.54	0.11
Un-covered industry	**Output (%)**	**Price (%)**	**Un-covered industry**	**Output (%)**	**Price (%)**
Farming	-0.01	0.01	Construction	-0.21	-0.03
Mining and Washing of Coal	-0.11	-0.11	Traffic, Transport and Storage	-0.02	-0.03
Mining of Metal Ores	-0.11	-0.06	Post	-0.03	0
Mining and Processing of Nonmetal Ores	-0.1	-0.06	Wholesale and Retail Trades	-0.07	-0.14
Manufacture of Textile	-0.01	0.01	Hotels and Catering Services	0.02	0.05
Manufacture of Leather, Fur, Feather Products	0.07	0.03	Financial Intermediation	-0.01	-0.03
Processing of Timbers and Manufacture of Furniture	-0.04	-0.01	Real Estate	0.02	0.18
Manufacture of Metal	-0.07	-0.01	Leasing and Business	-0.01	0

Products			Services		
Manufacture of Electrical Machinery and Equipment	-0.07	-0.01	Tourism	-0.05	-0.01
Manufacture of Communication Equipment, Computer	-0.01	0	Research and Experimental Development	-0.05	-0.03
Manufacture of Measuring Instrument and Machinery for Cultural Activity & Office Work	-0.03	0	Comprehensive Technical Services	0	0.01
Manufacture of Artwork, Other Manufacture	-0.01	0.01	Other Services	0	0.01
Scrap and Waste	0	-0.06	Education	0.02	0.02
Production and Distribution of Gas	-0.02	-0.02	Culture, Sports and Entertainment	-0.01	0.01
Production and Distribution of Water	-0.04	-0.01	Public Management and Social Organization	-0.02	0.01
Information Transmission, Computer Services and Software	-0.01	-0.03	Health Security and Social Welfare	0.02	0.04

Data source: SinoTERMCo2 simulation results

There are four reasons accounting for the changes of these industrial outputs:

1. Direct impact of carbon ETS (Direct Effect). The most effected industries are those covered by Pilot ETS, such as Mining and Processing of Nonmetal Ores and Other Ores, Smelting and Rolling of Metals, Chemical Industry, Production and Supply of Electric Power and Heat Power. Due to carbon ETS, the costs of Mining and Processing of Nonmetal Ores and Other Ores, Smelting and Rolling of Metals, Chemical Industry, Production and Supply of Electric Power and Heat Power increase by 0.25%, 0.14%, 0.14% and 0.11% respectively. Rise of both costs and prices eventually results in decreases in output.
2. Impact of macroeconomic demand (Income Effect). Manufacture of Leather, Fur, Feather Products, Hotels and Catering Services, Real Estate, Education, Health Security and Social Welfare are industries with expanding output, which is caused by the increase of consumption demand. 40% of Manufacture of Leather, Fur, Feather Products and Hotels and Catering Services are used in private consumption. In addition, shrinkage occurs in Construction, because the decline of total regional investment reduces demand for this industry.
3. Associated impact between upstream and downstream industries (Coupling Effects). 70%

of total output of Mining of Metal Ores are used by Smelting and Rolling of Metals, whose output declines because of carbon ETS, causing direct production shrinkage of Mining of Metal Ores. Similarly, goods from Mining and Processing of Nonmetal Ores are mainly used by three downstream industries: Nonmetal Minerals Industry, Construction and Chemical Industry, whose decline would lead to shrinkage of Mining and Processing of Nonmetal Ores. Extraction and Processing of Petroleum and Natural Gas and Processing of Petroleum and Nuclear Fuel also have similar effect. However, it is notable that price of Extraction and Processing of Petroleum and Natural Gas, Processing of Petroleum, Coking, Processing of Nuclear Fuel dropped by 0.03% and 0.13%. This is mainly because demand of downstream industries such as Traffic, Transport and Storage and Smelting and Rolling of Metals declines, leading to decreased price of oil processing, Processing of Petroleum, Coking, Processing of Nuclear Fuel, and finally causing falling price of upstream industries like Extraction of Petroleum and Natural Gas. In terms of Traffic, Transport and Storage, which mainly acts in international and regional trade flow, its output shows a decreased trend as both international and domestic trade decline.

4. Competition between provinces in the same industry (substitution effect). Farming, Manufacture of Textile, Manufacture of Foods and Tobacco, Manufacture of Artwork and other Manufacture in Hubei are export-oriented, and most of which are suppliers for other provinces. According to the model data, outflow of these industries consists of 40% of the total industrial output. The prices of these five industries rise by 0.01%, 0.01%, 0.04% and 0.01% respectively, leading to increased competitive ability of goods from other provinces and substitution of goods from Hubei.

B.5. Conclusion

This study constructs TermCO2 model and establishes scenarios based on current institutional factors of Hubei Pilot ETS, and then simulates its impacts on economy and environment of Hubei province. We found that:

(1) Hubei Pilot ETS has noticeable emission reduction effect, while its negative influence is relatively limited. Hubei Pilot ETS causes a 1% (about 6.98 million tons) decline of carbon emission, while GDP declines by 0.06% (about 1.48 billion Yuan). It indicates that elasticity of GDP to carbon reduction is 0.06, and every ton of carbon reduction leads to 212.09-Yuan loss of GDP on average.

(2) Economic structure of Hubei Province changes, with a decrease in investment and an increase in consumption. In 2014, employment and investment rate drops by 0.09% and 0.33% respectively. However, provincial household consumption increases by 0.35% due to the income distribution effect. Furthermore, the price level increases and CPI slightly rises by 0.02%.

(3) Different industrial outputs vary greatly from each other, which is mainly due to direct effect, income effect, coupling effects and substitution effect. Outputs of all 42 industries change with a range between −0.86% and 0.07%, 37 of 42 industries are negatively affected with

0.1

2% of simple average influence. By contrast, 5 industries benefit from this Pilot ETS as the average influence impact is 0.03%

Our study shows that ETS helps achieve emissions reductions at a lower cost. Therefore, China needs to accelerate the construction of a nationwide ETS based on the lessons learned from Pilot ETSs, and provide experiences and technical support for other developing countries to build up their ETS. Moreover, specific construction experiences from this paper indicate: firstly, the Hubei Pilot ETS covers only small numbers of entities but considerable emissions which not only helps Hubei achieve its emission reduction targets, but also avoid large impact on Hubei's economy; secondly, ETS has the income distribution effect caused by free allowance, thus policy makers need to give careful consideration to income flow of emission allowance in the design of ETS policies; thirdly, the impacts of ETS vary greatly on different industries, and influences on industrial output, employment and rate of capital return are larger in some sectors, therefore policy makers need to take into account the variation between industries in allowances allocation.