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Economic analysis of coal price–electricity price adjustment in China based on the CGE model

Y.X. He [a,*], S.L. Zhang [b], L.Y. Yang [a], Y.J. Wang [a], J. Wang [a]

[a] School of Business Administration, North China Electric Power University, Zhu Xin Zhuang, Bei Nong Lu No. 2, Changping District, Beijing, China
[b] Finance Department, Nanning Power Supply Bureau, Xingguang Street No. 43, Nanning, Guangxi Autonomous Region, China

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ABSTRACT

In recent years, coal price has risen rapidly, which has also brought a sharp increase in the expenditures of thermal power plants in China. Meantime, the power production price and power retail price have not been adjusted accordingly and a large number of thermal power plants have incurred losses. The power industry is a key industry in the national economy. As such, a thorough analysis and evaluation of the economic influence of the electricity price should be conducted before electricity price adjustment is carried out. This paper analyses the influence of coal price adjustment on the electric power industry, and the influence of electricity price adjustment on the macroeconomy in China based on computable general equilibrium models. The conclusions are as follows: (1) a coal price increase causes a rise in the cost of the electric power industry, but the influence gradually descends with increase in coal price; and (2) an electricity price increase has an adverse influence on the total output, Gross Domestic Product (GDP), and the Consumer Price Index (CPI). Electricity price increases have a contractionary effect on economic development and, consequently, electricity price policy making must consequently consider all factors to minimize their adverse influence.

1. Introduction

The power industry is one of the basic industries in the national economy, and electricity is one of the public's basic goods. Hence, electricity prices in China have long been fixed and strictly controlled by the Chinese government to maintain smooth economic development and a stable overall price level. In recent years, coal pricing has become more and more market-oriented, and coal price, which was artificially lowered during the price regulation period, increased rapidly due to its resource costs, production costs, and environmental costs, as well as the market's supply and demand conditions. Coal price, as the largest expense, greatly increases the cost of thermal power plants when it increases. In China, as the coal–electricity price linkage mechanism was not fully implemented, a large number of power enterprises incurred substantial losses and since then have urged the government to raise the on-grid power price to improve their business condition. In this work, the analysis and evaluation of the influence of the coal price increase on the electric power industry, especially on the electric power industry's cost and the influence of electricity price adjustment on the economy, were reported. These measures are of great importance for the review of the policies regarding electricity price and the intensification of the reform of the electric power industry.

The impact of the energy price increase around the world has drawn great attention. Oil is a vital input in the production process of an economy, and most of earlier studies have focused on oil price shocks or volatility. Rafiq et al. (2009), Zhang (2008), and Huang et al. (2005) adopted different methods to investigate the relationship between oil price shock and economic growth, and found that oil price shocks exert an adverse impact on economic growth. Rodríguez (2008) assessed the dynamic effect of oil price shocks on the output of the main manufacturing industries in six OECD countries and found that the pattern of responses to oil price shocks by industrial output was diverse across the four European Monetary Union (EUM) countries. Doroodian and Boyd (2003) used a dynamic computable general equilibrium (CGE) model to examine whether oil price shocks are inflationary in the United States. Their findings indicated that the aggregate price changes were largely dissipated over time at the aggregate level. Faria et al. (in press) developed an ARDL model to examine the impact of oil price shocks on China's export. They found that there was a positive correlation between China's exports and oil price due to the large labor force surplus. Huang and Guo (2007) constructed a four-dimensional structural VAR model to investigate the impact of oil price shock on China's real exchange rate. The results suggest that real oil price shocks would lead to a minor appreciation of the long-term real exchange rate due to China's lesser dependence on imported oil than its trading partners. In China, coal accounts for

* Corresponding author. Tel.: +86 010 51963733, +8610 51963776; fax: +86 010 80796904.
E-mail addresses: heyongxiu@ncepu.edu.cn, yxhe0941@sina.com (Y.X. He).

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about 70% of total energy consumption while oil accounts for about 20%; thus China's economy is coal-based rather than oil-based. Lin and Mou (2008) used a CGE model to examine the impact of coal and oil price increases on China's economy and concluded that the impact of energy price increases has contractionary effects, and the levels of contraction are different across industries. For most industries in China, the contraction effects of coal are two to three times that of oil for the same price increase. So, it is necessary to consider the different influences of coal, oil and other kinds of energy resources when making energy policies.

The impact of the electricity price increase has also drawn great attention recently, and many research studies are being conducted both in China and abroad. In Vietnam, Nguyen (2008) examined the impacts of increase in the electricity tariff in the long run on the marginal cost on prices of other products using a static input–output approach. He concluded that such an increase would drive up the prices of all other products. Although the aggregate price impact from such an increase is not large, it would be socially difficult to implement this increase at one time given that Vietnam is facing a high inflation rate. Silva et al. (2009) analyzed the environmental and social impacts of an increase in residential electricity tariffs, which range from 40% to over 100% in Montenegro. He reported that such a significant price rise would impose such a heavy burden on poor households that it might adversely affect the environment, and that the government of Montenegro should combine the tariff reforms with a carefully evaluated set of policy measures to mitigate the effect of the electricity price increase on the poor. Lin (2006) analyzed the impact of electricity tariff increases on various industries and provinces in China and quantified the impact of lower power quality on the industry using survey data. In this research, Lin adopted a C-D demand function to analyze the impact of electricity price increases on the price of end-use industrial products. He concluded that all industrial sectors are sensitive to increase in electricity prices, and that such an increase will lead to a corresponding rise in the prices of industrial products. Furthermore, he found that the direct impact of power shortages on industries was substantially larger than the cost of electricity supply and the magnitude of impact depended on the industrial mix, level of dependency on electricity, and the available alternatives. Zhang (2006) used a CGE model to explore the relationship between electricity price and industrial structure in China. The results showed that the cross-elasticity of each industry's output to electricity price is very low and that the industries with more electricity consumption are more sensitive to changes in electricity price. He et al. (2009) quantified the impact of the recent electricity price adjustment on related sectors and residents living in China based on the input–output method. She quantified the impact of electricity price increases on sectoral price, the change in CPI and end-use product price index based on the input–output table of 2002 of China under different scenarios. The CPI increases from 0.3% to 0.9% while the end-use product price increases from 0.32% to 0.97% when the electricity price increases from 5% to 15%. The conclusion is that such an adjustment would not have much adverse impact on the economy and residents' lifestyles; therefore, the impact of electricity price adjustments on each sector is different, and it is necessary to consider each sector's capacity for acceptance when a new price policy is made. Price volatility analysis has been reported in the literature for most competitive electricity markets around the world. However, only a few studies have been carried out that quantify price volatility in China's electricity market, which is the focus of the present paper. Furthermore, none of the above research examined the impact of coal price increases on the electric power industry and the impact of electricity price increase on China's economy from the angle of the industrial chain. For that reason, this paper reports the research conducted regarding this matter.

CGE models have been used to analyze the effects of a wide range of policy issues in both developed and developing countries. It can simulate the workings of an economy in which prices and quantities adjust to clear markets for products and factors. Equilibrium is achieved as a result of the independent optimising decisions of the producers and consumers of goods and services. CGE models are usually based on a comprehensive economy-wide database and can serve as a laboratory for policy. The CGE framework captures interrelationships among economic sectors and accounts for the repercussion effects of policy. For these reasons, this paper chose the CGE model to investigate the impact of the coal price and electricity price adjustment. However, a static CGE model, which we adopted in this paper, is incapable of modeling the long-term trend of the economy and a dynamic CGE model is needed to capture the characteristics of long-term trends in the economy, which will be the main challenge of our research in the future.

This paper is organized as follows: Section 2 discusses the CGE model, data, and parameters. Section 3 analyses the impact of coal price increases on the electric power industry. Section 4 analyses the impact of electricity price increases on China's economy, and Section 5 presents the conclusion.

2. Analytical framework

In the early 1960s, Johansen established a multi-sectoral growth model used to study the economic growth in Norway—considered to be the first practical CGE model. After nearly half a century, the CGE model was developed quickly in terms of the depth of theory, structure of the model, modeling technique, and application field. Particularly under the advocacy of international organisations such as the World Bank, almost all the developed countries and most of the developing countries have established their own CGE model, which is widely used in the field, such as for: the impact of taxation and tax reform, global trade, trade liberalization, economic integration, policy reform, price reform of agricultural markets, imperfect competition, income distribution, energy, natural resources, and environmental protection in developing countries (Zhou and Wang, 2006).

2.1. CGE model structure

CGE depicts the basic problems of total supply, total demand, and their balance. In the microeconomic analysis, firms and households are described as economic agents that take certain actions to maximize their evaluation functions under certain constraint conditions. That is, households select a different combination of consumer goods to maximize their utility under budget constraints, while firms choose the appropriate combination of intermediate inputs and factor inputs to maximize their profits, which are subject to certain technological constraints. Producers and consumers jointly decide the supply and demand function of the entire economic system, and the price and quantity where the equilibrium would meet. The CGE model is a set of equations describing the balance between the supply and demand of the economic system. The structure of the CGE model is shown in Fig. 1. Generally, the CGE model is composed of price equations, quantity equations, income equations, expenditure equations, market clearing conditions, and macroeconomic closure (Robinson, 1999), which are explained as follows:

(1) *Price equations*: on the import and export side, the model incorporates the "small country" assumption that world prices are exogenous. The composite commodities QQ consist of the constant elasticity of substitution (CES) aggregation of sectoral imports QM and domestic goods supplied to the domestic market (QD). Sectoral output QX is a constant

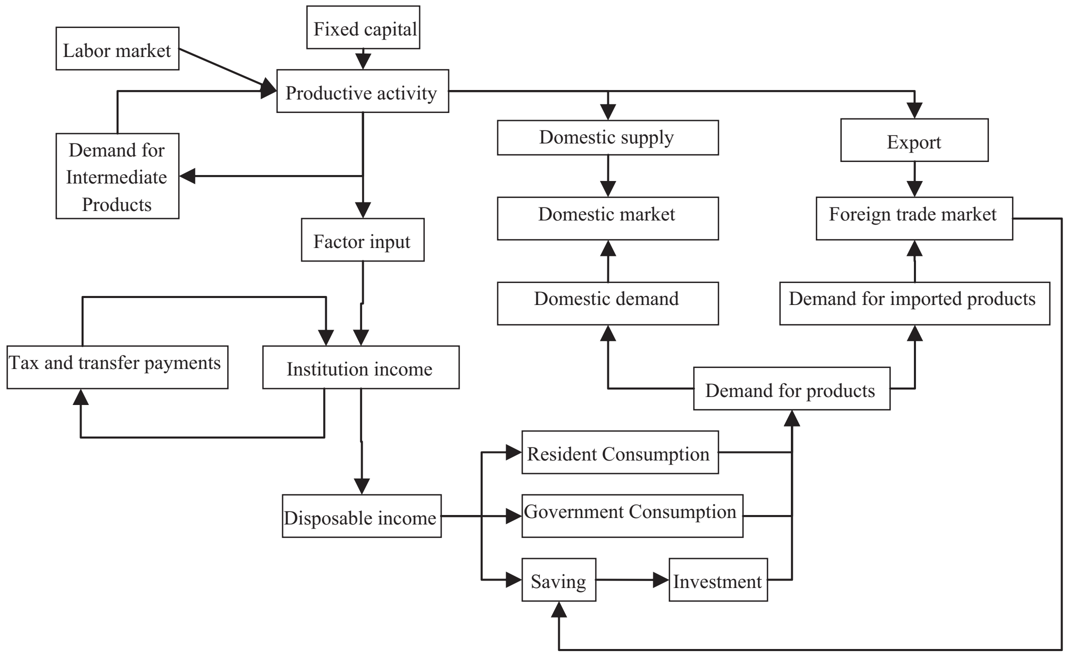

Fig. 1. Structure of CGE model.

elasticity of transformation (CET) aggregation of goods supplied to the export market (QE) and goods sold in the domestic market (QD). In the model, lower-case Latin letters a and c represent activities and commodities, respectively.

$$PQ_cQQ_c = PD_cQD_c + PM_cQM_c \tag{1}$$

$$PX_cQX_c = PD_cQD_c + PE_cQE_c \tag{2}$$

where PQ_c is the price of the composite good QQ_c, PD_c the price of commodities with domestic sales of domestic output QD_c, PM_c the import price in local currency units, PX_c the sector output price, and PE_c the export price in local currency units.

(2) *Quantity equations*: these equations describe the supply side of the model. In this part, a CET transformation function is adopted to combine exports and domestic sales, and a CES aggregation function to describe how imports and domestic products are demanded.

$$QA_a = \alpha_a^a(\delta_a^a QVA_a^{-\rho_a^a} + (1-\delta_a^a)QINTA_a^{-\rho_a^a})^{-1/\rho_a^a} \tag{3}$$

$$QX_c = a_c^t(\delta_c^t QE_c^{\rho_c^t} + (1-\delta_c^t)QD_c^{\rho_c^t})^{1/\rho_c^t} \tag{4}$$

$$QQ_c = a_c^q(\delta_c^q QM_c^{-\rho_c^q} + (1-\delta_c^q)QD_c^{-\rho_c^q})^{(-1/\rho_c^q)} \tag{5}$$

where QA_a is the activity output, QVA_a the quantity of (aggregate) value-added, $QINTA_a$ the quantity of aggregate intermediate input, $\alpha_a^a$the efficiency parameter in the CES activity function, δ_a^a the share parameter in the CES function, ρ_a^a the exponent of the CES function, a_c^t the shift parameter of CET function, δ_c^t the share parameter of CET function, ρ_c^t the exponent of CET function, a_c^q the Armington function shift parameter, δ_c^q the Armington function share parameter, and ρ_c^q the exponent of the Armington function.

(3) *Income equations*: this block maps the flow of income from value-added to institutions and ultimately to households. The households receive income from the factors of production (directly or indirectly via the enterprises) and transfers from other institutions. Enterprise incomes are allocated to direct taxes, savings, and transfers to other institutions. The government collects taxes and receives transfers from other institutions. Foreign savings (or the current account deficit) is the difference between spending and receipts.

$$YF_f = \sum_{a\in A} WF_f\overline{WFDIST}_{fa}QF_{fa} \tag{6}$$

$$YI_i = \sum_{f\in F} YIF_{if} + \sum_{i'\in INSDNG} TRII_{ii'} + trnsfr_{i\,gov}\cdot\overline{CPI} + trnsfr_{i,row}\cdot EXR \tag{7}$$

$$YG = TARIFF + INDTAX + HTAX - EXPSUB + trnsfr_{gov\ row}\cdot EXR \tag{8}$$

where YF_f is the income of factor f, WF_f the average price of factor f, $\overline{WFDIST}_{f\,a}$ the wage distortion factor for factor f in activity a, QF_{fa} the quantity demanded of factor f from activity a, YI_i the income of domestic non-government institution, YIF_{if} the income to domestic institution i from factor f, $TRII_{ii'}$, the transfers from institution i' to i, and $trnsfr_{i\,gov}$ the transfer from government to institutions. $\overline{CPI}$ is the producer price index, $trnsfr_{i,row}$ is the transfer from rest of the world to institutions, and EXR is the exchange rate. YG is the government revenue, which consists of tariff ($TARIFF$), indirect tax ($INDTAX$), direct tax ($HTAX$), export tax ($EXPSUB$), and transfers from the rest of the world ($trnsfr_{gov\ row}$).

(4) *Expenditure equations*: these equations describe the circular flow in the economy. Households distribute their expenditure on consumption and saving within disposable income; enterprises allocate their income on fixed investment and inventory. The government uses its income to purchase commodities for its consumption and for transfers to other institutions. Government consumption is fixed in real (quantity) terms,

Government consumption:

$$QG_c = \overline{GADJ}\,\overline{qg}_c \tag{9}$$

Households' consumption:

$$QH_h = \sum_h [\beta_{c,h}YI_h(1-MPS_h)(1-TINS_h)]/PQ_c \tag{10}$$

Investment demand:

$$QINV_c = \overline{IADJ}\,\overline{qinv}_c \tag{11}$$

where $\overline{qg}_c$ is the base-year quantity of government demand, $\overline{GADJ}$ the government consumption adjustment factor, $\beta_{c,h}$ the marginal share of consumption, YI_h the income of households, $\overline{MPS_h}$ the marginal propensity to save, $\overline{TINS_h}$ the direct tax rate, $\overline{IADJ}$ the investment adjustment factor, and $\overline{qinv}_c$ the base-year quantity of investment demand.

(5) *Market clearing conditions and macroeconomic closure:* this block defines the system constraints that the model economy must satisfy. The CGE model includes three macroeconomic balances: the government balance, the external balance (the current account of the balance of payments, which includes the trade balance), and the savings–investment balance. For the government balance, government savings is a flexible residual, while all tax rates are fixed. For the external balance, the real exchange rate is flexible, while foreign savings (the current account deficit) is fixed. For the savings–investment balance, real investment quantities are fixed.

Composite commodity market:

$$QQ_c = \sum_{a \in A} QINT_{c\,a} + \sum_{h \in H} QH_{c\,h} + QG_c + QINV_c + qdst_c + QT_c \tag{12}$$

Current account balance:

$$\sum_{c \in CM} pwm_c QM_c + \sum_{f \in F} trnsfr_{row\,f} = \sum_{c \in CE} pwe_c QE_c + \sum_{i \in INSD} trnsfr_{i\,row} + \overline{FSAV} \tag{13}$$

Savings–investment balance:

$$\sum_{i \in INSDNG} MPS_i(1-TINS_i)YI_i + GSAV + EXR\overline{FSAV} = \sum_{c \in C} PQ_c QINV_c + \sum_{c \in C} PQ_c qdst_c \tag{14}$$

where $QINT_{c\,a}$ is the intermediate use of commodity c in activity a, $QH_{c\,h}$ the quantity of commodity c consumed by households h, $qdst_c$ the stock change, pwm_c the import price in the foreign currency unit, QT_c is the quantity of commodity demanded as transactions service input, $trnsfr_{rowf}$ is the transfer from factor f to rest of the world, pwe_c the export price in the foreign currency unit, $\overline{FSAV}$ the foreign savings, $GSAV$ government savings, and EXR the exchange rate.

2.2. Database of CGE—social accounting matrix

A social accounting matrix (SAM) is a comprehensive, economy-wide data framework, typically representing the economy of a nation. Technically, a SAM is a square matrix in which each account is represented by a row and a column. Each cell shows the payment from the account of its column to the account of its row. Thus, the incomes of an account appear along its rows and its expenditures along its columns. The underlying principle of double-entry accounting requires that for each account in the SAM, total revenue (row total) equals total expenditure (column total).

In this paper, the SAM distinguishes the accounts for “activities” from the accounts for “commodities.” This separation of activities from commodities is preferred because it permits activities to produce multiple commodities while any commodity may be produced by multiple activities. The micro-SAM in this paper contains 17 sectors, as follows: agriculture; coal mining; natural gas, processing of petroleum, coking, and processing of nuclear fuel; other mining; food and tobacco; manufacture of textile and clothing; chemical materials and chemical products; manufacture of non-metallic mineral products; smelting and pressing of metals; manufacture of metal products; manufacture of machinery; production and supply of electric power and heat power; other industries; construction; transport, storage, and post; wholesale and retail trades, hotels and catering services; and other services.

In this paper, the “top–down method” was adopted to compile the micro-SAM of 2005. We first compiled a macro-SAM, and the micro-SAM was compiled according to the related numbers in the macro-SAM. The data of activities, commodities, and import and export columns came from the input–output table of 2005. The revenue and expenditure data of the government came from *China’s Fiscal Yearbook 2006*. The tax revenue data came from *China’s Tax Yearbook 2006*. The quantity of import and export commodities and the data of tariffs came from the *Customs Statistics Yearbook 2006*. The revenue and expenditure of households, enterprises, and government were adjusted based on the flow of funds accounts of the *China Statistical Yearbook 2006*. The macro-SAM of 2005 is shown in Table 1.

As the data predominantly came from diverse sources, the row totals and column totals were not equal in the compiled micro-SAM. We need to adopt a certain approach to balance the micro-SAM. The RAS method and cross-entropy methods are widely used to balance SAM (Qin, 2007). In this paper, the cross-entropy method was used to balance the micro-SAM under the General Algebraic Modeling System (GAMS) software environment.

2.3. Parameters of the model

There are two different types of parameters in the CGE model: the share parameters such as consumer and government’s consumption share, average savings rate, average tax rate, and the elasticity parameters such as elasticity of substitution between production factors, Armington elasticity, and CET elasticity. The former parameters can be fixed by the information provided in the SAM, but the latter ones are fixed exogenously. Based on the studies of other scholars (He et al. (2002); Zhai, 2005;

Table 1
Macro-SAM of 2005, unit: Billion Yuan.

	Activities	Commodities	Factors	Households	Enterprises	Government	$S-I$	ROW	Total
Activities		54,676.5							54,676.5
Commodities	36,050.9			7121.8		2660.5	7730.5	6849.5	60,413.1
Factors	16,091.8								16,091.8
Households			7773.2		3748.1	71.6			11,592.9
Enterprises			8318.7						8318.7
Government	2533.8	106.6		209.5	534.4				3384.3
Savings – Investment ($S-I$)				4261.7	4036.2	652.1		– 1016.3	7933.7
Rest of the world (ROW)		5833.2							5833.2
Total	54,676.5	60,616.3	16,091.8	11,592.9	8318.7	3384.3	7730.5	5833.2	

Willenbockel, 2006), this paper specifies the key parameters as given in Table 2.

The substitution elasticity between the total intermediate inputs and the total factor input needs to be set when the top-level production function is in CES form. In this paper, the substitution elasticity between total factor input and total intermediate input is 0.1 (Zhai, 2005).

3. Impact of coal price on electricity price

3.1. Background

In China, the total electricity output consists of thermal power, hydroelectricity, nuclear power, and others. Thermal power accounts for over 80% of the total generating capacity whilst hydroelectricity accounts for around 15%. Over 60% of the total coal output in China is supplied to generate electricity. Therefore, the fluctuation of coal prices has a great impact on the electric power industry. Since 1993, China has gradually liberalized the price of coal; from then, coal price has risen. Coal price should fully reflect its resource cost, production cost, environmental cost, and market supply and demand situations. During the period of government regulation, coal price was artificially lowered in China. Therefore, the upward trend of coal price was inevitable after market-oriented reforms, and it is reasonable to some extent. This is an adjustment of the irrational coal price in the market economy. The electric power industry shoulders a significant social responsibility due to its important impact on national security and social lives. Therefore, the price of electricity has long been controlled by the state. By the end of 2004, the National Development and Reform Committee (NDRC) promulgated a coal–electricity price linkage mechanism to mitigate the contradiction. This mechanism was carried out in May 2005 and July 2006. The electricity price increase could lead to an increase in the whole price level in the economy, as the coal price–electricity price linkage has not been implemented. The price of electricity does not follow the upper coal prices and makes corresponding adjustments, and thus the increased costs caused by the coal price should be absorbed by the power companies themselves. At the same time, coal contract price is lower than the market price, and coal enterprises are reluctant to perform coal contracts with power companies. This situation drives the coal supply to become tense, resulting in the power companies incurring losses.

Table 2
Elasticity parameters in the model.

Sector	Elasticity of substitution	Elasticity of transformation
Agriculture	2.2	4
Mining	3	4.4
Manufacturing	3.2	4.6
Electric power and heat power	0.9	0.5
Construction	2	4
Service	1.9	2.8

Fuel cost is the biggest cost item in thermal power plants, accounting for 70% of the variable costs. The rise in coal prices, especially the coal price for electricity generation, directly increases the operating costs of the enterprise and reduces corporate profits. In the global energy market, the energy product price has recently hindered the rapid rising trend: China's coal price also increased in response. In 2008, coal price doubled in less than six months. Under such a dramatic price increase, the cost of electric power enterprises increased vastly, and many electric power companies incurred losses. In this case, increase in the price of electricity to improve the operating conditions of power enterprises was a necessary measure to ensure power supply and to alleviate the coal price–electricity price contradiction. It is also of great importance to analyze the impact of the coal price increase on the electric power sector, especially on the total cost of the electric power sector when the electricity price policy was being made.

3.2. Scenario simulations

When using the CGE model for empirical analysis, we can change the properties of endogenous and exogenous variables to simulate certain policies under certain conditions. This paper follows this method to quantify the influence of coal price fluctuations and power price fluctuations. Firstly, we calibrate the parameters of the model using base-year SAM. Secondly, under the base scenario, we increase the sales price of coal and electricity exogenously to simulate how the economic system reacts to the price fluctuations. It should be noted that the electric power and heat power sector are treated as the electric power sector due to the unavailability of detailed data of the electric power sector and heat power sector. This paper assumes that the coal price increases by 5%, 10%, 15%, 20%, 40%, and 100%. By running the simulations in GAMS, the influence of coal price increases on the total cost of the electric power sector was determined. The simulation results are shown in Table 3.

As shown in Table 3, when coal prices fluctuate by 5%, 10%, 15%, 20%, 40%, and 100%, the total costs of the electric power sector rise by 1.03%, 2.03%, 2.98%, 3.91%, 7.39%, and 15.13%, respectively. This means that electricity price should be enhanced to maintain the profit level of the electric power sector, but the changing trend of price elasticity diminishes along with increase in coal price volatility. The average elasticity is 0.2 within 20% volatility, and the average elasticity is 0.168 within 40–100% volatility. This shows that the electric power company can mitigate and minimize the cost increase by optimising the management, allocating input factors, updating equipment, and improving productivity. It also shows that when the coal prices increase rapidly, it is reasonable and necessary to adjust the electricity price to compensate for the rising cost of enterprises, maintain normal production activities, improve the business situation of enterprises, and ensure a sustainable and stable electricity supply. It is also a necessary measure to exert the market mechanism, change enterprise function, and promote and deepen the electric power sector reform.

Table 3
Impact of coal price fluctuations on total costs in the power sector.

Coal price change range	**5%**	**10%**	**15%**	**20%**	**40%**	**100%**
Rate of change in electricity total cost (%)	1.03	2.03	2.98	3.91	7.39	15.13
Elasticity	0.205	0.203	0.199	0.196	0.185	0.151

4. Impact analysis of power price fluctuations

4.1. Impact and elasticity analysis of power price fluctuations on the price of downstream products

Electricity price changes have different impacts on different sectors; different sectors have different values in the government's industrial blueprint. Therefore, the single mode cannot be adopted when corresponding policies are made. To make wise decisions for the governors, it is important to know the different degrees of influence caused by electricity price on the different sectors.

This paper set four electricity price adjustment scenarios, namely, 5%, 10%, 15%, and 20%, and used the CGE model to simulate the scenarios. Under different circumstances, the changes in the product prices in related sectors are shown in Table 4 and Fig. 2.

The rising electricity prices result in the rising production costs of the different sectors. To maximize their profit, manufacturers have to raise product prices, as shown in Table 4. Different levels of electricity price adjustments have different influences on different sectors. Overall, the impact of electricity price adjustments is greater on the industrial sector than on the other sectors, and consequently, the high-electricity consumption sector is greater than the low-electricity consumption sector. As shown in Fig. 2, the sectors most affected by the electricity price increase are: the non-metallic mineral products industry, rolling processing industry, chemical industry, extractive industry, and metal manufacturing industry.

From the perspective of the price elasticity, as shown in Table 4, as the margin of the electricity price fluctuation increases, the weaker the influence will be upon the other sectors' product prices. This is the result of the motivation to maximize their profit, that is, when electricity price changes, the cost will increase accordingly in the other sectors and the other sectors will take corresponding measures to reduce the production cost to offset the cost increase result from electricity price change, for example, by strengthening the energy-saving management and improving the equipment efficiency.

4.2. Influence on the output of downstream products

The product supply and demand situation changes in accordance with the product prices and thus different sectors have to adjust their own production to meet the market's needs. With the simulation of CGE model, the production changes result from electricity price changes is shown in Table 5. The top 6 sectors most influenced by electricity price changes are presented in Fig. 3.

As shown in Table 5, the output of different sectors declines in various degrees as the production cost increases. All the cross-elasticities are negative, which means electricity price and product output are inversely proportional to each other. In addition, all the absolute values of the cross-elasticity coefficients are less than one, which means the product outputs of various sectors lack flexibility when electricity price changes. Lastly, the more electricity a sector consumes, the bigger is its absolute value of cross-elasticity coefficient. Except for the power generation and supply industry, the industries whose outputs declined the fastest with increase in electricity price are: non-metallic mineral products, metal smelting and processing, chemical industry, and mining and metal products. The reason is that these industries consume more power per output. Overall, the influence on the

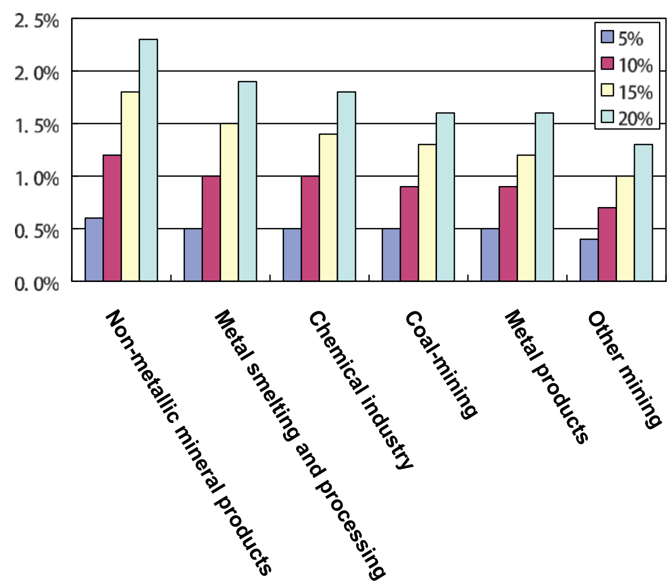

Fig. 2. Top 6 sectors whose sector price is impacted by electricity price fluctuations.

Table 4
Impact on price of downstream products of power price fluctuations.

Sectors	5%		10%		15%		20%	
	Price change (%)	Elasticity	Price change (%)	Elasticity	Price change (%)	Elasticity	Price change (%)	Elasticity
Agriculture	0.1	0.02	0.2	0.02	0.2	0.01	0.2	0.01
Coal-mining	0.5	0.10	0.9	0.09	1.3	0.09	1.6	0.08
Natural gas, petroleum, coking, and nuclear fuel	0.3	0.06	0.5	0.05	0.7	0.05	0.9	0.04
Other mining	0.4	0.08	0.7	0.07	1.0	0.07	1.3	0.06
Food and tobacco	0.3	0.06	0.6	0.06	0.8	0.05	1.0	0.05
Manufacture of textile and wearing	0.3	0.06	0.5	0.05	0.8	0.05	0.9	0.04
Chemical industry	0.5	0.10	1.0	0.10	1.4	0.09	1.8	0.09
Non-metallic mineral products	0.6	0.12	1.2	0.12	1.8	0.12	2.3	0.12
Metal smelting and processing	0.5	0.10	1.0	0.10	1.5	0.10	1.9	0.09
Metal products	0.5	0.10	0.9	0.09	1.2	0.08	1.6	0.08
Manufacture of machinery	0.3	0.06	0.6	0.06	0.9	0.06	1.1	0.05
Other industries	0.3	0.06	0.6	0.06	0.8	0.05	0.9	0.04
Construction	0.3	0.06	0.5	0.05	0.7	0.05	0.8	0.04
Transport, storage, and post	0.3	0.06	0.5	0.05	0.7	0.05	0.9	0.04
Wholesale and retail trades, hotels, and catering services	0.3	0.06	0.5	0.05	0.7	0.05	0.8	0.04
Other service	0.2	0.04	0.3	0.03	0.3	0.02	0.3	0.01

Table 5
Impact of electricity price fluctuations on sector output under different scenarios.

Sectors	5%		10%		15%		20%	
	Output change (%)	Elasticity	Output change (%)	Elasticity	Output change (%)	Elasticity	Output change (%)	Elasticity
Agriculture	−0.04	−0.008	−0.08	−0.008	−0.11	−0.007	−0.13	−0.006
Coal-mining	−0.34	−0.069	−0.59	−0.059	−0.84	−0.056	−1.04	−0.052
Natural gas, petroleum, coking, and nuclear fuel	−0.08	−0.017	−0.13	−0.013	−0.18	−0.012	−0.22	−0.011
Other mining	−0.36	−0.073	−0.69	−0.069	−0.91	−0.060	−1.09	−0.054
Food and tobacco	−0.04	−0.008	−0.10	−0.010	−0.15	−0.010	−0.19	−0.010
Manufacture of textile and wearing	−0.07	−0.014	−0.14	−0.014	−0.21	−0.014	−0.25	−0.012
Chemical industry	−0.35	−0.069	−0.67	−0.067	−0.97	−0.064	−1.14	−0.057
Non-metallic mineral products	−0.41	−0.082	−0.75	−0.075	−1.07	−0.071	−1.32	−0.066
Metal smelting and processing	−0.35	−0.070	−0.70	−0.070	−0.99	−0.066	−1.21	−0.060
Metal products	−0.33	−0.066	−0.57	−0.057	−0.76	−0.051	−0.95	−0.047
Manufacture of machinery	−0.24	−0.048	−0.46	−0.046	−0.68	−0.045	−0.90	−0.045
Electric power supply and heat supply	−0.32	−0.064	−0.64	−0.064	−0.91	−0.061	−1.14	−0.057
Other industries	−0.18	−0.037	−0.28	−0.028	−0.37	−0.024	−0.46	−0.023
Construction	−0.05	−0.010	−0.10	−0.010	−0.15	−0.010	−0.20	−0.010
Transport, storage, and post	−0.12	−0.024	−0.24	−0.024	−0.32	−0.021	−0.40	−0.020
Wholesale and retail trades, hotels, and catering services	−0.05	−0.010	−0.10	−0.010	−0.13	−0.009	−0.16	−0.008
Other service	−0.04	−0.009	−0.08	−0.008	−0.12	−0.008	−0.15	−0.007

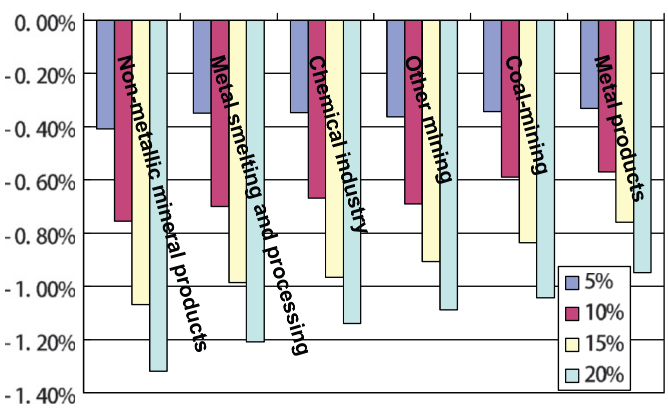

Fig. 3. Top 6 sectors whose sector output is impacted by electricity price fluctuation.

secondary industry is greater than on the primary and tertiary industries.

4.3. Influence on the CPI

As a way to measure the level of inflation, the CPI reflects the changes consumers pay for products and services. The three main targets of the government's macroeconomic management, namely: price stability, full employment, and balance between revenue and payments, are related to the steady development of the economy as a whole. The Chinese government has always attached the greatest importance to price stability. Thus, it is of great significance to focus on the question of: up to what extent will the electricity price adjustment affect the CPI? Table 6 shows how the CPI will change in different occasions.

The CPI increases by 0.4%, 0.7%, 1%, and 1.2% when the electricity price increases by 5%, 10%, 15%, and 20%, respectively. The elasticity becomes smaller, and the average number becomes 0.07 when the power fluctuation range is at 20%. Price stability is one of the most important macroeconomic targets of the Chinese government because it relates to stability and quality of life. As such, governors have to consider what influences the electricity price changes will make on the CPI; generally, the change in CPI within 1% is mild. The above results show that the increase in electricity price within 15% will at most affect CPI by 1%. However, this does not mean that increase in electricity price within 15% is acceptable at any time. There are many factors influencing CPI, such as macro-fiscal policy and monetary policy, among others. The electricity price should be adjusted at the appropriate time, and the policy-makers should consider the price situation as a whole to minimize the influence caused by electricity price changes on the whole price of the market and the development of the economy.

Table 6
Impact of electricity price fluctuations on CPI under different scenarios.

Electricity price fluctuation	5%	10%	15%	20%
Change of CPI (%)	0.4	0.7	1	1.2
Elasticity	0.08	0.07	0.07	0.06

4.4. Influence on other macro-indicators

As the CGE model shows, the product price change of one sector affects the others, resulting in changes in product prices and output of other sectors, which are closely related to the import and export levels of the trade sector, consumption level of the residents and government departments and GDP, as shown in Table 7.

In Table 7, the output level of the whole society declines while the electricity price increases. This turns out to be a non-linear relationship. The GDP also declines in accordance with the decline in the level of output. A country's consumer goods have two parts: imports and domestic products. Its output can also be divided into two parts: domestic consumption and exports. Increase in electricity price results in the price increase of other products of the different sectors. Under the premise of CES and CET, for domestic consumers, if the prices of the export goods remain the same and life is not so affluent, it is a wise choice to consume a certain proportion of export goods instead of domestic goods. For the domestic manufacturers, to pursue the maximum profit, reduce the export, and further open up the domestic market, the best choice is to maintain the prices of the export goods. As shown in Table 7, the quantity of imports increases in accordance with increase in electricity price, while the quantity declines.

Table 7
Impact of electricity price fluctuations on macro-indicators under different scenario.

Indicators	5%		10%		15%		20%	
	Rate (%)	Elasticity	Rate (%)	Elasticity	Rate (%)	Elasticity	Rate (%)	Elasticity
Total output	−0.16	−0.032	−0.31	−0.031	−0.45	−0.030	−0.56	−0.028
GDP	−0.13	−0.026	−0.24	−0.024	−0.34	−0.023	−0.43	−0.022
Import	0.11	0.022	0.23	0.023	0.35	0.023	0.47	0.023
Export	−0.14	−0.028	−0.31	−0.031	−0.52	−0.034	−0.75	−0.037
Households' income	−0.22	−0.044	−0.49	−0.049	−0.82	−0.055	−1.19	−0.059
Households' expenditure	0.35	0.070	0.65	0.065	0.88	0.059	1.08	0.054
Government expenditure	0.18	0.036	0.29	0.029	0.33	0.022	0.37	0.018

Both the total household consumption and the government consumption increase to a certain extent when the product prices of the different sectors increase. Considering the consumption structures of the two (the government consumption focuses on the primary and tertiary industries goods), the household consumption increases and is larger than the government's consumption increase. On the other hand, this means that it costs consumers more to maintain the former consumption structure and utility level. If income declines, then the level of resident welfare will also decline, worsening the welfare situation.

5. Conclusions

In China, the coal price–electricity price linkage mechanism was not fully implemented, which led to large losses for thermal power enterprises. Based on the CGE model, the analysis results show that a 100% coal price increase will raise the electricity production cost by 15.13%. The price elasticity varies from 0.15 to 0.2 when the coal price increase varies from 5% to 100%. From this point, it is reasonable to adjust electricity prices when coal price increases rapidly. It is also necessary to improve the business condition of electric power enterprises and intensify the restructuring of the electric power industry.

The simulations of the electricity price increases show that the industries largely influenced by such increases, like the non-metallic mineral products industry, and smelting and pressing of metals and chemicals industry, are high-electricity consuming sectors. The problems of over-expansion and overcapacity are widespread in the electrolytic aluminum industry, ferroalloy industry, and calcium carbide industry. The electricity price increase is conducive to optimising the rational allocation of power resources, constraining blind expansion of power-consuming industries, conserving energy, promoting energy efficiency, and improving environmental quality. The electricity price increase will affect the CPI, and an increase in electricity price within 20% will lead to a maximum 1.2% increase in CPI. Increases in electricity price also affect macroeconomic indices such as total output, GDP, import and export, income of residents, and consumption expenditure. Overall, the electricity price increase has a contractionary effect on the macroeconomy. Sector price increases, which are induced by the electricity price increase, curb the total consumption level. From the perspective of welfare economics, increases in electricity price will lead to the deterioration and decline of social welfare.

In summary, this paper recommends the following policies for electricity prices:

1) It is reasonable to adjust electricity prices with the coal price increases up to a certain degree. It is a necessary measure to compensate for electricity production costs and meet the reasonable profit requirements of the electric power industry. However, the adjustment has to reflect the changes in cost and curb unreasonable monopoly profits. At the same time, attention must be given to the amplitude of price adjustment to avoid the negative effects of excessive adjustment.
2) The impact of electricity price increases is different between sectors. The government can implement discriminating electricity prices between high-electricity consuming sectors to optimize the industrial structure and curb the blind expansion of high-energy consuming sectors.
3) The coal price–electricity price linkage mechanism should be improved further. A maximum cap on electricity prices should be set up according to the overall price level and consumers' spending capacity, and interim measures should be taken to intervene with the coal industry's actions when necessary.
4) The reform of the electric power system and electricity pricing system should be promoted and deepened, which will lead to the favorable opportunity of moderating electricity supply and demand. This is a fundamental way to resolve the contradiction between coal price and electricity price, promote the rational use of electricity, and realize the sustainable development of the economy.

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