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General equilibrium evaluation of deregulation in energy sectors in China

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The central government in China has implemented ambitious energy policy reforms since 1978. An important pillar of these reforms is the deregulation in the energy markets which manifests itself in the formation of energy prices. This study examines the macroeconomic impacts of deregulation in China using an applied CGE model and counterfactual policy simulations. The results point to substantial welfare improvement. Sectoral results point to a reallocation of resources and diversion of economic activities more toward domestic services.

Keywords: energy; China; deregulation; CGE model

JEL classifications: C68; L4; O53; P28

1. Introduction

Energy consumption in China has increased remarkably along with rapid economic growth since 1978. Economic growth and the changing structure of the economy have especially increased the demand for electricity, and this has subsequently determined the electricity generation capacity (Liu, Zhang, and Girardin 2014). China is currently the largest consumer of energy as well as the largest greenhouse gas emitter in the world. Since the late 1990s, the total energy supply has fallen short of total energy consumption, and energy imports, especially of oil, have increased considerably. In the decade 2001–2011, net energy imports accounted on average 5.4% of total energy use (World Development Indicators (WDI)), and net imports of crude oil increased by 14.8% annually (National Bureau of Statistics of China). The central government in China has implemented ambitious energy policy reforms since 1978 to tackle the problem of supply shortage and to secure energy supply to sustain economic growth. The gradual deregulation in the energy sector is an important element of these recent energy policy reforms. The government retains a strong control over the energy sector. The aim of the deregulation process, as elsewhere, was the establishment of a business environment that relies on free market principles. One expects deregulation to result in efficiency improvement and the elimination of distortions brought about by strong regulation prior to the reforms. Efficiency and environment-related issues have only recently been included in the government's energy policies. Price deregulation plays a central role during the deregulatory process.

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Ma, Oxley, and Gibson (2010) and Girardin, Liu, and Zheng (2014) provide an extensive review of studies on energy reforms in China's energy sector, with the latter focusing on the electricity sector.[1] Among these studies, we review those using computable general equilibrium (CGE) modeling approach to investigate the macroeconomic impact of energy reforms in China. Liang, Fan, and Wei (2009) analyzed the macroeconomic impact of energy efficiency improvement and found evidence for the rebound effect, i.e., improvements in energy efficiency bring about increase in energy consumption and CO_2 emissions. He et al. (2010) examined the impact of rising coal prices on the economy through its impact on electricity prices. They found that the impact of the coal price rise on electricity, prices diminish as coal price rises and the change in electricity prices impacts on the economy adversely. In another CGE study, He et al. (2011) estimated electricity demand price elasticities. Lin and Jiang (2011) estimated energy subsidies using price-gap approach and analyzed energy subsidy reforms. They found that a reduction in energy subsidies results in a fall in energy demand and has negative macroeconomic impacts. Liu and Li (2011) investigated the impact of the reforms about fossil energy in China and found using a CGE model and price-gap approach that removing oil subsidies have a stronger negative impact on the economy than removing coal subsidies. There are also studies examining energy policies in China using quantitative techniques other than the CGE model. For instance, Kahrl and Roland-Holst (2009) used input–output techniques to examine the structural changes in the energy sector, and Li (2010) used an econometric model to analyze sustainable energy strategies. Finally, Chen and He (2013) analyzed the economic impacts of deregulation in the electricity generation sector in China using a CGE model. They found that deregulation results in potential efficiency improvement in electricity generation and an increase in social welfare. Based on empirical findings, they recommend that the central government enhances competition further in the retail segment of electricity supply.

Deregulation is an integral component of the recent reforms in the Chinese energy market. It plays an important role due to the impact of price signaling in determining the level of consumption and production. There are contrasting views on the impact of the changes in prices on the energy market. For instance, Liu, Zhang, and Girardin (2014) argued that a change in the prices for end users does not stimulate electricity generation. On the other hand, Lin and Jiang (2011) found that energy subsidies led to below-supply-cost energy prices for consumers and consequently to low energy efficiency. There is a need to examine the macroeconomic impacts of recent energy subsidy and energy price reforms in China. It is noteworthy that energy subsidies have been provided in a complex way, not always in the form of direct cash subsidies. In the natural gas and oil sectors, the government mostly provides direct oil price subsidies and gas price subsidies to either refineries or end users. In the case of electricity and coal sectors, Liu and Zhang (2012) argued that government maintains its control through three plan prices, i.e., the plan price for the sale of coal to power generators, the plan price for the sale of electric power to the power distributor, and the plan price for the power distributor to resell the power to end-users. They mentioned that the plan price is a negotiated outcome that takes into account the interests of various stakeholders and the bargaining mechanism compromises public interest by instituting a 'soft price constraint' on the costs of the firm (Liu and Zhang 2012). As a result, the high-cost power firm gets a higher price, while the low-cost power firm gets a lower price, and the grid buys electricity from both high-cost and low-cost firms and resells the electricity to end-users, hence the inefficient firms cannot be selected out from the market (Liu and Zhang 2012).

Ma, Oxley, and Gibson (2010, 125) argued that 'although the existing literature considers all policy reforms, they do little more than describe them'. Previous studies examining the impact of energy market reforms, especially those targeting energy prices and energy subsidies, in a variety of countries generally found that such reforms result in an increase in energy prices and a reduction in energy consumption (and hence reduction in greenhouse gas emissions) while improving energy efficiency (e.g., Anderson and McKibbin 1997; IEA 1999; Saunders and Schneider 2000; Hosoe 2006; Akkemik and Oğuz 2011). The aim of this study is to examine the possible effects of the deregulation of prices in the Chinese energy market using an applied CGE model. The impact of the removal of subsidies to both consumers and producers is examined through counterfactual simulations.

The remainder of the study is organized as follows. Section 2 reviews energy policies and related institutional reforms in China. Price deregulation is reviewed in Section 3. The structure of the CGE model is described in Section 4, and the data used in the benchmark solution are presented in Section 5. Section 6 reports the simulation results. Finally, Section 7 wraps up and concludes.

2. A review of energy policies in China

Early energy policies in China had a supply-side focus because the most important issue was supply security after the post-1978 reforms. Particularly, the government emphasized the supply of coal in the 1980s (Wu 2003). Coal was important because it was the primary source of electricity. The heavy reliance on coal created a large burden on the transportation system due to uneven geographic distribution of fossil fuel reserves in China.[2] To solve the long-distance transportation issue, four large-scale infrastructure-building projects were undertaken, namely, *Bei Mei Nan Yun* (north-to-south coal transfer), *Bei You Nan Yun* (north-to-south oil transfer), *Xi Qi Dong Shu* (west-to-east natural gas transmission), and *Xi Dian Dong Song* (west-to-east electricity transmission). However, as a result of persisting energy shortages and partially due to environmental concerns, the government turned its attention to energy efficiency and energy conservation after the 1990s.[3]

The policies and programs addressing energy efficiency and energy conservation in China can be categorized into three types: laws, comprehensive plans, and operational programs. At the legislation level, the 30th Session of the Standing Committee of the 10th National People's Congress approved the revision of the *Energy Conservation Law* in October 2007. The general strategy and long-term target of the Chinese energy policies were presented in comprehensive plans including the Medium and Long-term Energy Saving Plan (*Jieneng zhongchangqi zhuanxiang guihua*) announced in 2004 and five-year plans. In the Medium and Long-term Energy Saving Plan, the government announced its aim to reduce the energy intensity of GDP from 26.8 tons of standard coal equivalent (sce) per 1000 yuan (in 1990 prices) in 2002 to 22.5 tons sce per 1000 yuan in 2010 and to 15.4 tons sce per 1000 yuan in 2020 (Yuan et al. 2008). In the 11th Five-Year Plan, the government updated its target of reducing energy intensity by 20% between 2005 and 2010. Later on, the 12th Five-Year Plan (2011–2015) stated a further 16% cut in energy intensity from the 2010 level, and a boost in the use of non-fossil fuel energy sources to 11.4% of primary energy consumption (CPC Central Committee, 2011). These comprehensive plans were followed by several implementation programs and decisions for daily operation.

The highlights at the operational level are reported in *10 Key Energy-saving Program* and *Top-1000 Energy-consuming Enterprises Program*. The former focuses on energy conservation by industries[4]. And the latter targets 1008 highest energy-consuming enterprises in nine major energy-consuming industries.[5] During 2006–2010, the investment from the central budget designated to energy conservation was around RMB 30 billion and supported 5200 projects of 10 Key Energy-saving Program nationwide (NDRC 2011a). In the case of the Top-1000 Energy-consuming Enterprises Program, NDRC signed agreements with local governments, and then, local governments signed agreements with enterprise within their jurisdictions. The agreements include energy-saving targets for each enterprise. The achievement of those targets has been included in the provincial government cadre evaluation system. NDRC announced recently that the Top-1000 Energy-consuming Enterprises Program saved 150 million tons sce during 2006–2010, which is 50 million tons sce more than its original target (NDRC 2011b).

Institutional reforms and organizational restructuring of China's energy agencies in the central government since the late 1980s are also noteworthy. Restructuring aimed to integrate the separated powers and authority of related regulatory bodies into one regulatory body. The first round of restructuring involved the establishment of the Ministry of Energy in 1988; however, the ministry was dismantled in 1993 due to failure to adjust the vested interests of related regulatory bodies (Tsuchiya 2011). The second round of restructuring was accompanied by the restructuring of central administration in 1998. The commercial arms of various regulatory bodies were separated and eventually corporatized, while regulatory functions were mainly allocated to State Development Planning Commission, State Economic and Trade Commission (SETC), and Ministry of Land and Natural Resources (Wu 2003). Among the three, SETC's power and authority was increased and it became the main regulator in the energy sector until 2003 (Wu 2003). In 2003, accompanied by the establishment of the National Development and Reform Commission (NDRC), China's Energy Bureau was set up under the jurisdiction of NDRC. Since then, the Energy Bureau has been responsible for energy supply, while the divisions responsible for energy efficiency have been in different departments of NDRC (Zhou, Levine, and Price 2010). However, the Energy Bureau was not able to improve the administrative efficiency and integrate the powers from multiple regulatory bodies, because its administrative level was lower than or equal to other relevant agencies. As a result, in 2005, the State Council established an Energy Leadership Group, which was later reorganized as State Energy Commission (SEC) in 2008, with the Premier serving as the head. In addition, the Energy Bureau was reorganized in 2008 as National Energy Administration (NEA), under the jurisdiction of the NDRC but operating rather independently. It is reported that NEA is in charge of implementation and SEC is in charge of coordination among relevant agencies, and NEA is possibly a transitional institution toward the establishment of the Ministry of Energy (Xinhua Net 2010; Wu 2010).

3. A review of deregulatory reforms of energy prices in China

Deregulation in energy prices is an important pillar of energy market reforms in China. At the start of the reform process, strict controls on energy prices by the government were abolished in 1982, and a dual track pricing system was introduced wherein a portion of energy products out of plan allocation could be sold at market prices (Wu 2003; Hang and Tu 2007). In the late 1990s, the dual track pricing system was abandoned, while plan allocation of energy was gradually abolished in the late 1990s. Despite three decades of reform, the government still maintains price interventions to a certain extent in electricity, coal, oil, and natural gas sectors.

Electricity and coal prices are inextricably connected to each other due to the heavy reliance of power generation on coal. Girardin, Liu, and Zheng (2014) provide an extensive overview of reforms in electricity pricing. Although electricity prices for end-users remained under government control, coal prices have been largely liberalized since the 1990s. The mismatch between fixed retail electricity prices (on-grid and end-user tariffs) and varying coal prices has created significant distortions in the power sector. The price of coal sold to non-electricity generation sectors was controlled by the government until 1992, while the price of the coal sold to electricity generation sector (thermal coal or electricity coal) was strictly controlled by the government until 2001. Since 2002, the government has announced benchmarking/guidance prices of electricity coal, so there is an indirect price control (Zhao, Liu, and Lu 2009). The plan price for selling power is often too low to cover the cost of coal at the market price, and the plan supply of the cheaper electricity coal is limited, so the regulated electricity prices leave many utilities in economic distress (Zhou, Levine, and Price 2010).[6] Additionally, because coal producers have no incentive to supply coal for electricity, and the power firms cannot afford the market price of coal to produce more power in excess of the planned output, surplus in power generation capacity and the shortage of power supply in the economy often coexist (Liu and Zhang 2012).

Similarly, the regulated price for oil products is low compared to the price of crude oil, which is linked to the international market, so the crude oil producers make substantial profits, while oil refineries suffer tremendous losses. The major reform of oil pricing regime started in June 1998, with a switch from the dual track system to benchmarking/guidance pricing mechanism adjusted on the basis of international markets. Crude oil price is determined based on the weighted average price of Brent, Dubai, and Minas markets. The NDRC adjusts benchmarking retail prices of oil products every 10 working days, and the refineries can price their products taking into account the input prices such as transportation costs, taxes, and profit margin. However, the cap on price increase sustains, and the NDRC is allowed to intervene in the prices of refined oil products if international crude oil price is higher than $130 per barrel.

In the natural gas sector, the government attempted to unify the state plan price and the market price into a benchmarking/guidance pricing system in 2005. Since then the retail price of natural gas has been calculated based on a formula incorporating production costs, delivery costs, and profit margin of distributors. However, since the price set by the NDRC does not adequately reflect production and delivery costs, domestic gas prices are low compared to the international price. Due to increasing imports, national energy giants such as PetroChina suffer huge losses from selling imported natural gas in the domestic market. Low prices also reduce the incentives of PetroChina and other energy giants such as Sinopec and CNOOC to import natural gas or invest in shale gas exploration – whose prices are linked to international crude oil prices – and consequently lead to supply shortage. In 2013, the government reformed the pricing regime for gas nationwide, suggesting a 15% increase in benchmarking/guidance prices for non-residential users. However, residential users were excluded from the 2013 reform, and the government provided subsidies and/or relevant preferential policies to gas-fired power companies, heat suppliers, and taxi industry. The price of liquefied natural gas for July 2013 delivery to Asia was about $0.54 per cubic meter (RMB 3.3), so natural gas is still highly underpriced in China (Ma 2013).

Despite the recent attempts toward price deregulation, the government in China still provides substantial amounts of subsidies to both consumers and energy-supplying producers. Particularly, the government has provided large subsidies to address the mismatches between regulated retail electricity prices, refined oil product prices respectively with the costs of raw materials (Zhou, Levine, and Price 2010). While the definition of 'subsidy' is a debated issue, OECD (1998) classified various forms of energy subsidies into (i) support that increases the revenue of a sector (e.g., direct transfers to energy-producing firms, minimum prices, state-guaranteed sales), (ii) support that lowers the costs of production (e.g., preferential tax exemptions, tax rebates, reduced import tariff rates, low-interest credits to energy-producing sectors), and (iii) direct support not linked to production or inputs (e.g., direct subsidies to households). These subsidies reduce the costs to both energy suppliers and consumers. Governments generally justify subsidies for expectations such as stimulation of energy production, which is especially important under circumstances of energy supply shortages, and alleviation of poverty through supply of energy to low-income households at low prices. In China, subsidy reforms have become a crucial aspect of the recent deregulatory reforms. Lin and Jiang (2011) argued that the subsidies to consumers in China encourage the consumption of fossil fuels, reduce energy efficiency, and exacerbate the environmental problems. These social and economic issues are listed among the main issues to be dealt with as part of the goals of the energy market reforms. Due to these social and economic implications, it is necessary to measure the costs and benefits of energy subsidy reforms.

4. Structure of the CGE model

This study develops a multi-sector CGE model with Walrasian characteristics similar to Akkemik and Oğuz (2011) and Hosoe (2006).[7] An important feature of the model is that it allows producers to substitute among energy sources. Although it is difficult to substitute some energy sources, electricity in particular, the possibility of substitution may still have important policy implications. For instance, energy-saving policies and environmental policies especially address substitution of fossil fuels with other sources of energy.

4.1. Production and trade

Figure 1 portrays output structure. Production technology is represented by a nested production function involving value-added generation at the first level and gross output at the second level. Value-added (VA) is a constant returns to scale Cobb–Douglas function of capital (K) and labor (L), as follows:

$$VA_i = \alpha_{Qi} L_i^{\theta_i} K_i^{1-\theta_i} \tag{1}$$

where i denotes sectors, α_Q is the shift parameter of the production function, and θ is the share of labor in total factor income. There are 13 sectors in the model. Factor demands in equilibrium are derived from the first-order conditions. Due to the constant returns to scale assumption, prices equal marginal cost.

Intermediate inputs used in the production process are composed of energy inputs and non-energy inputs. Intermediate inputs (MI) are expressed as fixed proportions of gross output (Q) using the technical coefficients (a_{ij}) derived from the input–output

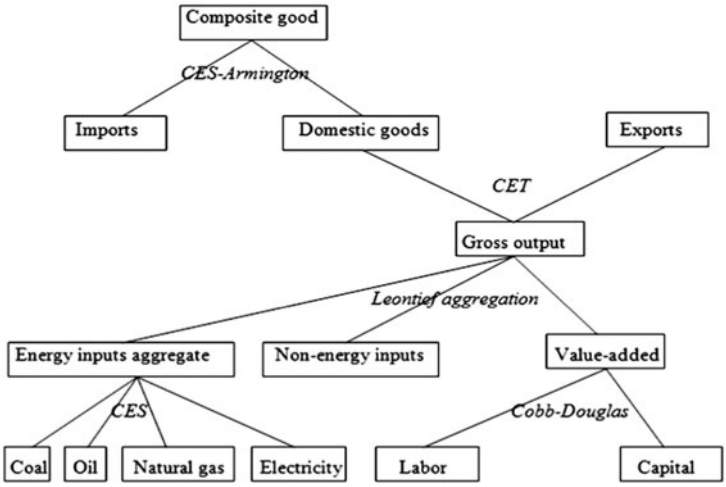

Figure 1. Output structure of the model.

tables i.e. $MI_j = a_{ij}Q_j$, where a_{ij} refers to intermediate input use of sector j from sector i. An important issue is the substitution between intermediate inputs. We assume that energy inputs (coal, oil, gas, and electricity) used in the production of energy are not substitutable.[8] Coal is the most important energy input used in the production of electricity. In the non-energy sectors, we assume that energy inputs are substitutable and the production technology is represented by a constant elasticity of substitution (CES) type of aggregation function for energy inputs.

At the top level of the nested production function, gross output Q is a Leontief function of value-added and intermediate (material) inputs (MI), as follows:

$$Q_i = \min\left[\frac{VA_i}{a_{VAi}}, \frac{Q_{1i}}{a_{1i}}, \ldots, \frac{Q_{13i}}{a_{13i}}\right] \tag{2}$$

where a_{VA} and a_{ji} are the shares of value-added and intermediate inputs in gross output, respectively. There are 13 intermediate inputs, of which four are energy inputs and the rest are non-energy inputs. We do not allow substitution across energy inputs in the energy-producing sectors. In other sectors, we assume that energy inputs are substitutable with a CES aggregation function.

As Hosoe (2006) argues, assuming constant returns to scale in the energy sectors is not realistic since these sectors are characterized by scale economies due to high fixed costs. Accordingly, we assume increasing returns to scale in the energy sectors and constant returns to scale in the remaining sectors. Subsequently, the energy sectors earn a markup (μ) over marginal cost which is shown in the equation for the value of capital:

$$p_{Ki}K_i = (1 + \mu_i)p^0_{Ki}K^0_i \tag{3}$$

The superscript 0 denotes the market-clearing level, and p_K denotes the price of capital. Since the markup enters the value of capital equation, it affects the value-added and output in the energy sectors. Due to lack of reliable estimates, we assume a markup rate of 10%.[9]

Constant elasticity of transformation (CET) function with imperfect substitution aggregates exports (X) and domestic sales (D) into gross output for producers. Similarly, Armington CES function with imperfect substitution aggregates domestic goods and imports (M) into Armington composite goods (E) for consumers. These relations are shown as follows:

$$Q_i = \alpha_{Ti}[\beta_{Ti}X_i^{-\rho_{Ti}} + (1-\beta_{Ti})D_i^{-\rho_{Ti}}]^{\frac{1}{\rho_{Ti}}} \tag{4}$$

$$E_i = \alpha_{Ei}[\beta_{Ei}D_i^{-\rho_{Ei}} + (1-\beta_{Ei})M_i^{-\rho_{Ei}}]^{-\frac{1}{\rho_{Ei}}} \tag{5}$$

In Equations (4) and (5), α, β, and ρ terms are, respectively, scale, distribution (share), and elasticity parameters. First-order conditions of the CET and Armington CES functions yield the optimal amounts of domestic supply, exports, and imports as follows:

$$\frac{M_i}{D_i} = \left(\frac{\beta_{Ei}}{1-\beta_{Ei}} \cdot \frac{p_{Di}}{p_{Mi}}\right)^{\frac{1}{1+\rho_{Ei}}} \tag{6}$$

$$\frac{X_i}{D_i} = \left(\frac{\beta_{Ti}}{1-\beta_{Ti}} \cdot \frac{p_{Xi}}{p_{Di}}\right)^{\frac{1}{\rho_{Ti}-1}} \tag{7}$$

4.2. Institutions

The level of utility (U) of the representative household is defined as Cobb–Douglas utility function which is determined by consumption levels (C):

$$U = \prod_i C_i^{\alpha_{Ci}} \tag{8}$$

where α_C is the consumption share.

Households earn factor income from the services of capital and labor they render to enterprises. They then make their decisions on consumption and savings as a fixed proportion of their income.

The government earns direct tax revenues from firms and households in the form of income tax and indirect tax revenues from production activities. The government then makes a decision between the level of public expenditures and transfers.

4.3. Equilibrium conditions and macro closure

We specify the Walrasian equilibrium conditions for product and factor markets and the saving–investment account. Excess demand equals zero in both product and factor markets. In the product market, aggregate demand equals aggregate supply in each sector. Aggregate demand is composed of private household consumption, firms' investment expenditures, government spending, and spending by firms on intermediate inputs.

In the factor market, the sum of sectoral factor demands equals total factor endowments. We assume that capital is sector-specific (immobile), while labor is mobile. Then, sectoral labor demands (with inelastic labor supply) and inter-sectoral profit rates adjust to achieve equilibrium.

As a macroeconomic rule, total investments equal total savings, which comprises household savings, foreign savings, and public savings. We assume that public, foreign, and aggregate savings are exogenous. The saving rates of economic agents are constant. Therefore, our model is principally savings-driven. In the current account, we assume a fixed exchange rate so that the current account adjusts to achieve the external balance. Due to Walras' Law, one of the equilibrium conditions needs to be dropped to avoid overdetermination. Accordingly, we drop the saving-investment equilibrium equation.

4.4. Numeraire

We choose a weighted supply (gross output) price index as the numeraire. The weights are the relevant shares of the sectors in total output.

5. Data

5.1. Benchmark data

Benchmark data for the analysis are organized into a social accounting matrix (SAM) using the data obtained from the *Input-Output Tables of China 2007*, which is available from *China Statistical Yearbook* (CSY) published by the National Bureau of Statistics, *2007 Flow-of-Funds Statistics*, which is available from CSY 2009, and *2007 Balance of Payments Statistics*, which is available in CSY 2008. Annual average exchange rate used in constructing the balance of payments data is 7.604 RMB per US dollar. We assume that current transfers from the rest of the world to domestic sectors (except for the government) are all destined to the enterprises account.

The sectoral disaggregation in the SAM emphasizes the energy sectors for the purpose of this study. There are 13 sectors in the activities/commodities accounts, narrowed down from the original list of 42 sectors (see Table 1). A list of these sectors is provided in Table 2. In addition, the SAM includes two factors of production accounts (capital and labor), three institutions (households, firms, and government), a capital (saving-investment) account, and a rest of the world account. An aggregated version of the SAM (macro-SAM) is presented in Table 3.

Energy subsidy rates are computed from Lin and Jiang (2011). The subsidies for households and industries are shown in Table 4. Half of the subsidies were allocated to the oil sector in 2007. Households receive most of the subsidies on electricity, while the industry is negatively subsidized for electricity usage. In other words, there is a transfer from industries to households.

5.2. Calibration

Some important parameters (e.g., sectoral distribution parameters in the production function, indirect tax rates, import tariff rates, and institutional income tax rates) are calculated using the benchmark data from the SAM. Armington and CET elasticity parameters are determined exogenously. The remaining parameters in the model are calibrated in the standard fashion using SAM data.

6. Empirical results

6.1. Policy experiments

Price deregulation and energy subsidy reforms in general are expected to establish a competitive market and hence improve efficiency, which in turn should bring production costs down. Lesourd, Liu, and Genoud (2014), for instance, estimated inefficiency in coal-fired electricity generation plants around 9% compared to the cost frontier. Therefore, there is still room for efficiency improvement. Previous studies examining the impact of energy subsidy reforms found that removal or reduction of subsidies to

Table 1. List of sectors in the 42-sector SAM.

I–O code	Description
1	Agriculture
2	Coal mining and processing
3	Crude petroleum and natural gas products
4	Metal ore mining
5	Non-metal ore mining
6	Food products and tobacco processing
7	Textile
8	Wearing apparel, leather, furs, down, and related goods
9	Wood processing and furniture manufacture
10	Paper, printing, manufacture of cultural, educational, and sports products
11	Petroleum processing, coking, and nuclear fuel
12	Chemicals
13	Non-metal mineral products
14	Metal smelting and pressing
15	Metal products
16	Machinery and equipment
17	Transport equipment
18	Electric equipment and machinery
19	Telecommunication equipment
20	Instruments-meters-cultural and office machinery
21	Other manufacturing products
22	Scrap and waste
23	Electricity, steam, and hot water production and supply
24	Gas production and supply
25	Water production and supply
26	Construction
27	Transport and warehousing services
28	Post services
29	Information communication, computer services, and software
30	Wholesale and retail trade
31	Hotel and restaurant businesses
32	Financial services
33	Real estate
34	Leasing and business services
35	Research and development
36	Technological services
37	Management of water resources, environment, and public utility
38	Civil services and other services
39	Education
40	Sanitation, social security, and social welfare
41	Culture, sports, and entertainment
42	Public administration and social organizations

consumers and producers lead to more efficient resource allocation and therefore economic gains in the form of, for instance, higher GDP, efficient use of energy, and improvement in public balances (e.g., Anderson and McKibbin 1997; Saunders and Schneider 2000). Efficient use of energy by end-users, especially households, due to higher energy prices would also discourage energy-intensive production or lead the energy suppliers to seek more efficient or renewable energy sources. An indirect impact of subsidy reforms may be a reduction in greenhouse gas emissions resulting from excess use of fossil fuels.

Table 2. List of sectors in the 13-sector SAM.

Acronym	Description	I–O codes
AGR	Agriculture	1
COAL	Coal mining and processing	2
OIL	Crude petroleum products	3
MIN	Mining	4–5
LIGHT	Light industry (food, beverages, textile, clothing, wood, paper)	6–10
REF	Petroleum processing, coking, and nuclear fuel	11
HEAVY	Heavy industry (chemicals, metal products, machinery, equipment)	12–22
ELEC	Electricity and steam production and supply	23
GAS	Natural gas production and supply	24
WATER	Water production and supply	25
CONS	Construction	26
TRAN	Transport services	27
SERV	Services	28–42

To analyze the economy-wide impact of the deregulation of prices in the energy sector, this study employs two policy experiments. In the first experiment, all markups in the energy sectors are removed, effectively setting up a competitive market. Subsidies provided to energy-supplying firms are embedded in the markups. In this scenario, the pressure on prices is lifted, and energy prices are expected to increase. In fact, the foremost result of deregulation observed in most countries is an increase in prices. An increase in energy prices will then directly influence consumers and energy-intensive activities, heavy industry in particular. In the second experiment, in addition to the removal of the markups for energy suppliers, all subsidies provided to consumers are removed, effectively giving an energy price shock to the economy. In this scenario, we expect the economy to reallocate resources and consumers and firms to redesign their economic decisions due to the change in energy prices.

6.2. Simulation results

6.2.1. Macroeconomic results

The preliminary results from the policy experiments obtained from the model are discussed briefly in this section. The macroeconomic results of the simulation experiments are presented in Figure 2. We calculate the percentage changes in (i) the weighted average of energy prices for consumers, (ii) the weighted sum of total energy consumption by households, and (iii) welfare change as demonstrated by Hicksian equivalent variations.

The results in the first simulation reveal that the cost of energy for households increases by 15.7%. This increase in energy prices leads to a reduction in household energy consumption by about 14%. The overall impact on welfare, however, is positive, accounting for about 1.1% of GDP. This is mainly because of the welfare-enhancing positive changes in household consumption levels in some important sectors. It is noteworthy that the share of electricity consumption in total household consumption is only about 2.0%.

The results for the second experiment in Figure 2 show that after the elimination of subsidies for both households and firms, the weighted energy price explodes and rises

Table 3. China macro-SAM for 2007 (billion RMB).

	ACT	COM	LAB	CAP	ENT	HH	GOV	INV	ROW	Total
ACT	0	70,7611.1	0	0	0	0	0	0	111,248	818,859.1
COM	583,982.8	0	0	0	0	72,345.4	28,794.3	98,019	0	783,141.5
LAB	117,284.5	0	0	0	0	0	0	0	0	117,284.5
CAP	79,071.8	0	0	0	0	0	0	0	0	79,071.8
ENT	0	0	0	79071.8	0	0	8343.2	0	0	87,415
HH	0	0	117,284.5	0	0	0	3748	0	0	121,032.5
GOV	38,520	0	0	0	16,209.4	877	0	0	0	55,606.4
INV	0	0	0	0	54,675.1	33,855.1	6661.4	0	2827.4	98,019
ROW	0	75,530.4	0	0	16530.5	13,955	8059.5	0	0	114,075.4
Total	818,859.1	783,141.5	117,284.5	79,071.8	87,415	121,032.5	55,606.4	98,019	114,075.4	

Notes: ACT: activities, COM: commodities, LAB: labor, CAP: capital, ENT: enterprises, HH: households, GOV: government, INV: investment, ROW: rest of the world.

Table 4. Energy subsidies in China in 2007 (billion RMB).

	Total subsidy	Subsidies to industry	Residential subsidies
Coal	53.2	53.2	0
Oil	189.0	179.8	69.3
Electricity	38.1	−164.4	202.6
Gas	76.4	68.3	8.1
Total	356.7	136.8	219.9

Source: Adopted from Lin and Jiang (2011).

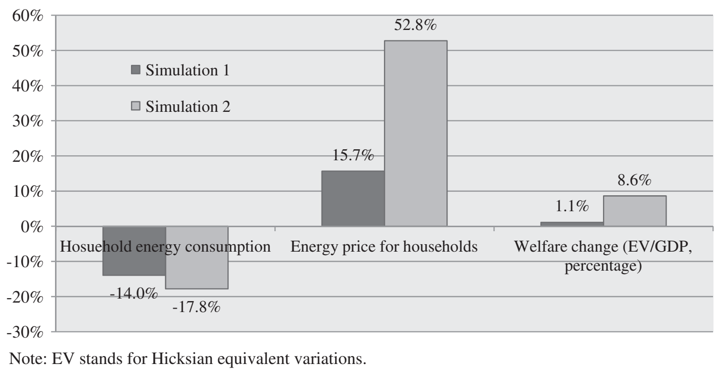

Figure 2. Simulation results: macroeconomic results (% change from baseline).
Note: EV stands for Hicksian equivalent variations.

by 52.8%. This, however, does not lead to a very large decline in energy consumption. Energy consumption declines by 17.8%. The large change in the wage level (a rise by 6.9%) allows for a larger increase in consumption and hence production. The sectoral results in the next section show that the change in production and consumption is much larger in this experiment. Therefore, the net impact on welfare is as high as 8.6% of GDP. In other words, the removal of all distortions in energy prices results in a welfare gain in China which amounts to about 8.6% of GDP.

In a recent comparable study, Lin and Jiang (2011) found using a CGE model that if all energy subsidies, which sum up to 1.43% of GDP in 2007, are removed, the resulting increase in energy prices leads to a reduction in social welfare by 2.0% and therefore a reduction in GDP by 1.56%, while energy intensity improves (a decline by 3.56%).

6.2.2. *Sectoral results: removal of markups for firms in the energy sector*

Sectoral results are presented in the upper panel of Table 5. The disaggregated results imply a reallocation of resources away from mining, energy, and the relatively more energy-intensive manufacturing and transport services sectors and toward domestic services.[10] As a result, on the supply side, the composition of output, domestic supply, and value-added in the economy changes in favor of domestic services. Energy consumption decreases in transport services, mining, and various manufacturing industries. Energy consumption increases in the domestic service sectors. On the demand side,

Table 5. Simulation results: sectoral results (% change from baseline scenario).

	Q	*E*	*L*	*D*	*r*	*w*	*X*	*M*	*C*
Simulation 1									
AGR	−0.92	−0.38	−0.96	−0.47	1.85	1.84	−9.73	3.05	−0.64
COAL	−1.95	−1.90	−2.80	−1.95	−0.95	1.84	0.00	0.00	−7.66
OIL	−3.04	−1.89	−3.03	−3.06	−1.19	1.84	0.00	0.00	0.00
MIN	−2.86	−1.79	−4.77	−2.78	−1.84	1.84	−8.15	0.50	0.00
LIGHT	−0.22	−0.02	−0.37	−0.08	2.52	1.84	−6.12	1.82	−0.24
REF	−1.84	−1.73	−3.42	−1.86	−0.49	1.84	0.00	−0.34	1.13
HEAVY	−1.88	−1.00	−3.69	−1.15	−1.85	1.84	−7.06	−0.26	0.62
ELEC	−2.25	−2.22	−2.25	−2.25	−0.41	1.84	0.00	0.00	−15.46
GAS	−2.82	−2.83	−2.83	−2.83	−0.98	1.84	0.00	0.00	−7.68
WATER	0.02	0.03	0.03	0.02	1.88	1.84	0.00	0.00	2.10
CONS	0.11	1.70	0.16	1.95	−9.99	1.84	0.00	−4.42	5.44
TRAN	−3.31	−1.56	−8.19	−2.92	0.00	1.84	−45.86	36.73	−25.10
SERV	2.59	2.09	4.85	2.44	−6.92	1.84	6.05	−9.81	9.43
Simulation 2									
AGR	1.26	1.12	1.16	1.26	1.93	6.92	−1.79	1.46	0.37
COAL	−4.46	−4.56	−6.48	−4.57	−4.43	6.92	0.00	0.00	−2.80
OIL	−2.79	−4.48	−10.62	−4.51	−5.20	6.92	0.00	0.00	0.00
MIN	−6.20	−6.95	−11.34	−6.85	23.37	6.92	−15.06	−4.72	0.00
LIGHT	9.67	9.20	15.38	9.67	2.58	6.92	−11.28	9.47	3.87
REF	−2.16	−2.21	−4.07	−2.21	0.00	6.92	0.00	−1.52	4.60
HEAVY	−3.64	−5.19	−9.87	−4.04	−3.63	6.92	−13.80	−1.42	4.47
ELEC	−3.75	−3.82	−6.48	−3.82	17.74	6.92	0.00	0.00	−20.63
GAS	−3.85	−3.83	−6.48	−3.85	−2.57	6.92	0.00	0.00	−2.55
WATER	6.41	6.41	10.12	6.41	−9.90	6.92	0.00	0.00	4.07
CONS	2.56	−22.90	−30.92	2.15	0.00	6.92	−24.43	13.00	3.44
TRAN	0.48	1.73	1.73	1.57	0.00	6.92	18.96	−28.62	8.52
SERV	3.14	2.26	2.26	3.16	−3.83	6.92	−15.92	2.57	1.76

Notes: *VA*: value-added, *Q*: output, *E*: Armington composite, *L*: labor demand, *D*: domestic supply, *r*: cost of capital, *w*: labor wage, *X*: export, *M*: import, *C*: household consumption.

households increase their consumption of manufacturing products, construction services, and domestic services. The increase in consumption in these sectors is mainly due to the reduction in supply prices in these sectors. The improvement in welfare results primarily from the increase in household consumption of domestic services.

In foreign trade, the transport services sector is affected the most. The increase in the domestic energy prices seem to increase imports and reduce exports in this sector. Manufacturing exports are also negatively affected by the increase in energy prices. This might pose important challenges for price competitiveness for Chinese manufactures in world markets.

While resources are reallocated in the economy, wages for labor and rates of return to capital are readjusted. Wage rates increase by 1.8%. Return to capital, on the other hand, decreases in most sectors and rises in agriculture and light manufactures. These industries are relatively less energy-intensive. Therefore, energy prices lead to reallocation of labor and readjustment of the returns to capital across domestic production activities.

Figures 3 and 4 rearrange the results for selected variables by focusing on the energy sectors only. Figure 3 presents the results for output, Armington composite goods, and household consumption. The rise in energy prices affects these variables

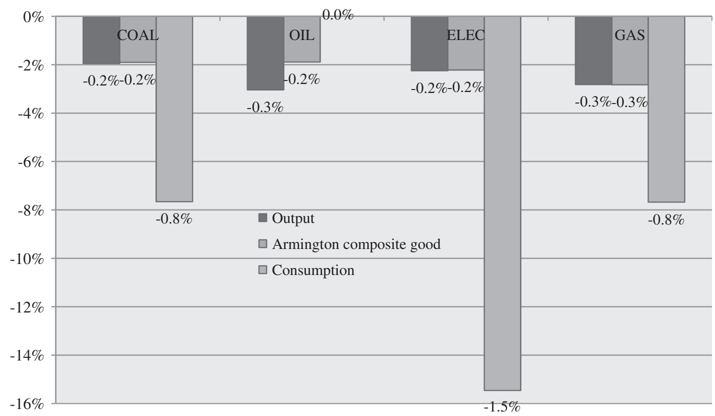

Figure 3. Percentage changes in output, Armington composite goods, and private consumption for energy sectors (Simulation 1).

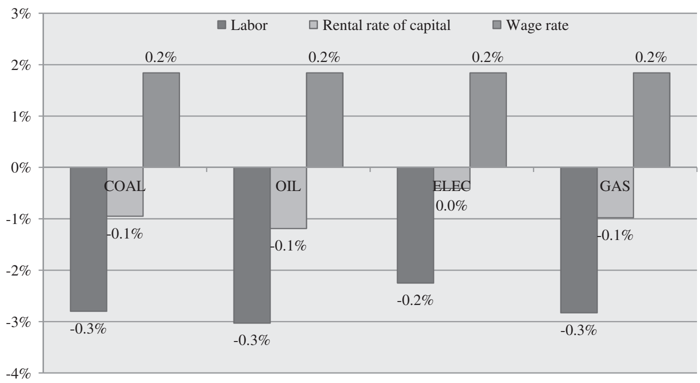

Figure 4. Percentage change in employment, wage rate, and rental rate of capital for energy sectors (Simulation 1).

negatively in energy sectors. Electricity exhibits the largest decline in household consumption (15.5%). The percentage decline in output, on the other hand, is higher in oil (3.0%) and gas (2.8%) compared to coal (2.0%) and electricity (2.3%). The decline in output is also manifest in declining demand for labor in the energy sectors between 2.3 and 3.0% in Figure 4. Similarly, the return to capital in the energy sectors decreases by 0.4–1.0%.

These findings point to a reallocation of productive resources in the Chinese economy and a readjustment of returns to these resources toward services sectors. Therefore, the results imply that the services sectors may gain importance in the Chinese economy and more resources would be devoted to services after full accomplishment of energy price deregulation.

Our results are comparable to those in Chen and He (2013), which also found that for the deregulation in the electricity sector, production efficiency and social welfare in the economy increase. We enlarge the scope to four energy sectors in China and show in a counterfactual scenario that social welfare improves to a greater extent with deregulation, especially if all subsidies and markups are removed fully.

6.2.3. Sectoral results: removal of markups and energy subsidies

The sectoral results for this experiment are presented in the lower panel of Table 5. The reallocation of labor toward light industries and services sectors is observable from the results. As in the case of the previous experiment, the domestic services sector benefits the most from such reallocation of resources. The use of energy shrinks in heavy industries but increases in light industries and domestic services. Therefore, the rise in energy prices due to the removal of subsidies has mixed sectoral results. In particular, household consumption of coal and electricity is hit the hardest. On the one hand, household consumption greatly increases in most manufacturing industries and the transport services sector. On the other hand, household consumption of domestic services rises sharply. The positive impact on consumption is a factor contributing to positive welfare gain in the economy.

In foreign trade, most exports are affected negatively, while imports of agriculture, light industries, and construction greatly increase. The negative impact on exports and the positive impact on imports are visible. Therefore, it can be said that the reallocation of resources due to the removal of all distortions would lead to shrinking trade surplus in China. This finding has important policy implications. The impact on manufacturing exports, in particular, is negative.

The removal of subsidies triggers a reallocation of available labor and leads to changes in the returns to the factors of production. While resources are reallocated in the economy, wage rates and rates of return to capital change. Wage rates increase by 6.9%. The rental rates of capital decrease in domestic services sector slightly but increase remarkably in the agriculture, mining, and electricity sectors.

The results for selected variables for the four energy sectors are presented in Figures 5 and 6. The results for energy sectors in Simulation 2 are qualitatively the same as in Simulation 1. As in the Simulation 1, the hike in energy prices affects consumption, output, and demand for Armington composite goods adversely in the energy sectors. The electricity sector, again, exhibits the largest decline in household consumption (20.6%), while the reduction in household consumption in coal and natural gas sectors

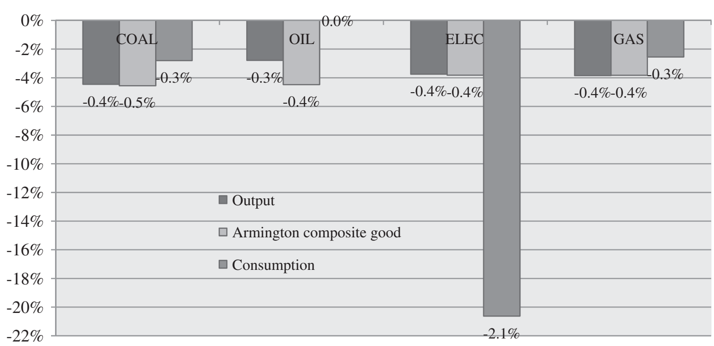

Figure 5. Percentage changes in output, Armington composite goods, and private consumption for energy sectors (Simulation 2).

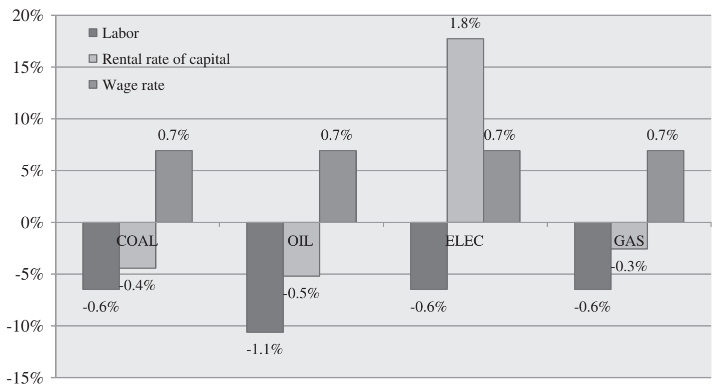

Figure 6. Percentage change in employment, wage rate, and rental rate of capital for energy sectors (Simulation 2).

is far less than in the previous simulation. The decline in output in the energy sectors, between 3.8 and 4.5%, is slightly higher than in Simulation 1. Similarly, reflecting on the higher contraction in output in the energy sectors, the reduction in labor demand and the erosion in the rate of return to capital in the energy sectors is higher in Simulation 2 compared to the first simulation.

The removal of subsidies leads to a shift of labor mainly toward domestic services and light manufacturing industries and an accompanying readjustment of factor returns, as in the previous experiment. The policy implication of this experiment is that these sectors are most likely to benefit from such a policy shock. The sectors negatively affected are mining, oil supply, construction, and heavy industries.

6.2.4. Implications for CO_2 emissions

We do not model the environmental impact of the policy shocks within the CGE model. However, it is possible to make some calculations based on energy consumption and CO_2 emissions data from IEA (2011). Table 6 reports CO_2 emissions and energy consumption data for China in recent years. In 2007, China emitted 6028.4 million tons of CO_2 and consumed 2805.08 million tons sce of energy. Therefore, China emitted 2.15 tons of CO_2 per ton sce of energy consumed in 2007. The relevant figure in 2009 was 2.23, and the average for the period 1990–2009 was 2.19. This figure has been rising steadily since 2001. Using the figures for 2007, it is possible to make some inferences about the environmental impacts of the results obtained from the two simulations.

In the first simulation, we found that the removal of markups for the energy-generation firms leads to a reduction in energy consumption by households by 14%. Using the average CO_2 emission per energy consumption figures for 2007 in Table 6, the reduction in energy consumption translates to a reduction in CO_2 emissions by 841.6 million tons. Using the world total for CO_2 emissions in 2007 reported in the World Bank's WDI database, this corresponds to a reduction at the global level by 2.8%. In the second simulation, the simultaneous removal of markups and energy subsidies leads to a decrease in household energy consumption by 17.8%. Using the data in Table 6, this leads to a reduction in CO_2 emissions by about 1073.1 million tons, which is equivalent to 3.6% of the global emission level. The environmental impact of the removal of subsidies along with the removal of markups is much larger.[11]

Table 6. CO_2 emission and energy consumption data for China (1990–2009).

	CO_2 emission (million tons)	Energy consumption (million tons sce)	CO_2 emission per ton sce
1990	2211.3	987.0	2.24
1991	2325.1	1037.8	2.24
1992	2428.5	1091.7	2.22
1993	2627.2	1159.9	2.27
1994	2745.3	1227.4	2.24
1995	2986.1	1311.8	2.28
1996	3160.8	1351.9	2.34
1997	3100.8	1359.1	2.28
1998	3156.4	1361.8	2.32
1999	3046.6	1405.7	2.17
2000	3037.3	1455.3	2.09
2001	3083.3	1504.1	2.05
2002	3308.2	1594.3	2.08
2003	3827.6	1837.9	2.08
2004	4552.4	2134.6	2.13
2005	5062.4	2360.0	2.15
2006	5602.9	2586.8	2.17
2007	6028.4	2805.1	2.15
2008	6506.8	2914.5	2.23
2009	6831.6	3066.5	2.23

Source: IEA (2011).

It is noteworthy that a large portion of the CO_2 emissions result from electricity generation, which uses coal heavily, and manufacturing and construction sectors. According to IEA (2011) data, total CO_2 emission resulting from fuel combustion in 2009 was 6831.6 million tons; electricity and heat generation accounted for 48.2% of total CO_2 emissions, and the manufacturing and construction sectors accounted for 33.3%. Therefore, CO_2 emissions by sectors are governed by sectoral energy input use. This relationship is captured by energy input usage by sectors in the model.

7. Conclusion

This study examines the results of the hypothetical removal of markups in the energy sectors and removal of subsidies granted to households and firms in China using benchmark data for 2007. The results point to substantial welfare gain and substantial reductions in CO_2 emissions. The results at the sectoral level point to the possibility of a more domestic demand-led economic growth opportunity for the Chinese economy. This is evident from the reallocation of resources toward domestic services sector and light industries. Expansion of domestic demand would reduce China's dependence on foreign trade to some extent.

The empirical result of this study that the removal of subsidies brings about welfare gain implies that there is a need for subsidy reforms in China. Lin and Jiang (2011) argued that to make the best use of energy subsidies, the Chinese government should shift its attention from supply-side subsidies to demand-side subsidies.

This study attempts to quantify the possible effects of subsidy reforms by hypothetically removing all energy subsidies and removing all markups for energy-supplying firms in China. However, the methodology has its own limitations as well. First of all, there is no publicly available data for subsidies. The study employs the estimates by Lin and Jiang (2011). Therefore, the results of this study would be interpreted with caution. In addition, for the purpose of this study, a static CGE model was sufficient. For future projections, a dynamic version of the model is needed. Since the study does not aim to analyze the effect of the energy reforms on poverty, it does not disaggregate the households in the model.

Disclosure statement

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Notes

1. Ma, Oxley, and Gibson (2010) show that previous studies focus on (i) causal relationship between energy consumption and GDP, (ii) decomposition of the changes in energy intensity, (iii) substitution between energy and non-energy inputs, (iv) convergence of energy prices, and (v) the reforms in the energy market.
2. There is substantial mismatch between the geographical distribution of fossil fuel reserves and centers of economic activities in China. According to Naughton (2007, 342), northern half of China has about 90% of the gas and oil and 80% of the coal. Almost half of total coal reserves are concentrated in a three-province region in north China, comprising Shanxi, northern Shaanxi, and western-inner Mongolia. Mountainous southwestern and western China is abundant in hydropower resources. Meanwhile, economic activities in China have been concentrated in the southeastern coast.
3. Shi (2008, 367) reports that 85% of the sulfur dioxide, 70% of the smoke, and 60% of the nitrogen oxides emitted into the atmosphere in China result from the burning of coal.
4. The contents of 10 Key Energy-saving Program cover coal-fired industrial boiler retrofits, district cogeneration projects, waste heat and pressure utilization projects, petroleum conservation and substitution projects, motors energy conservation projects, energy system optimization projects, building energy conservation projects, green lighting projects, government agency energy conservation projects, and construction projects of energy-saving monitoring and testing, and technology service system (NDRC 2006b).
5. 1008 highest energy-consuming enterprises refer to those enterprises which consumed 180,000 tons sce or higher in 2004 (NDRC 2006a).
6. In 2004, NDRC announced the notice on suggestions to establish co-movement mechanism between coal prices and electricity prices. It states that the price adjustment cycle for coal prices and electricity prices is six months. If coal price in the current cycle is 5% higher than that of the previous cycle, the price of electricity should be adjusted accordingly. However, the mechanism does not run effectively (Zhao, Liu, and Lu 2009). Despite the setbacks, the Chinese government has continued to be reform-minded. In the 12th Five-Year Plan for Energy Development for 2011–2015, released in 2013, the government reiterated its intention to ‘speed up’ electricity pricing reform. On 25 December 2012, the NDRC declared that it would stop intervening in coal prices, and would set prices such that power generators could pass on 90% of the burden to distributors and end-users if coal prices rise more than 5% over 12 months.
7. There are some other studies examining the economic impact of energy policies using CGE models such as Chisari, Estache, and Romero (1999), Coupal and Holland (2002), and Kerkela (2004).
8. Note that the current model is a static model, and therefore, this assumption reflects the situation at the base year. There may be changes, of course, in the future in input substitution in energy-generation sectors. For instance, if the country decides to transform from fossil fuels

to cleaner energy, it can simply build more wind turbines or nuclear power plants. In that case, the model can be adjusted to reflect the change in input use in energy generation. On the other hand, substitution of inputs may not be easy for some energy firms.

9. Sun, Guo, and Zeng (2012, 94) report that the government uses the markups to set energy prices and to allow investors to recover their investments. They also admit that reliable data on costs and markups are not available and prices are generally determined annually by way of bilateral negotiation between the state and the firms.
10. Note that since capital is fixed in the model, the only reallocated resource is labor.
11. If 2009 figures, instead of 2007, in Table 6 are used, the reduction in CO_2 emissions amounts to 953.7 million tons for the first simulation and 1261.0 million tons for the second simulation. Using the WDI data, these figures correspond to about 3.2 and 4.2% of global CO_2 emissions.

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