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The origin and prospect of billion-ton coal production capacity in China

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ABSTRACT

This study thoroughly explored the origin of coal production capacity using simultaneous equation model (SEM) with 2006–2014 data sample. Scenario analysis, including market regulation scenario (MRS), central policy strengthening scenario (CPE), and two-level government policy strengthening scenario (TPE), was also conducted to determine the degree of influence on resolving overcapacity considering construction industry development, policy control, forecasted coal production capacity, and future supply and demand changes. Results show that (1) construction industry development plays a significant and sustained role in the advancement of four major coal-consuming industries. (2) Construction industry development, coal prices, industrial policy, and natural resources positively affect capacity investments in coal production. (3) The policies put forward by the central government inhibiting capacity investments exert greater effect than those promoting capacity investments. (4) The central and local governments make production policies based on their independent interests has minimal success. And the effect of refinement policies by local governments is generally better than that of those by the central government. (5) Under MRS, CPE, and TPE, the coal production capacity (CPC) will reach 5.399, 5.044, and 4.952 billion tons, respectively, by 2020; the coal supply will reach 4.304, 4.174, and 4.139 billion tons, respectively, by 2020. The coal demand will reach 4.03 billion tons by 2020. By 2020, coal supply is projected to be at least 109 million tons greater than coal demand. From industrial restructuring and upgrading to refining and implementing capacity policies are suggested along with the market-oriented reform of the supply side of coal industry.

1. Introduction

Since the 1980s, persistent and widespread overcapacity has been frequently observed in the economic operations of China. The settlement of overcapacity has become an urgent problem as the economy of China has gradually entered a new normal (Zheng and Zhou, 2014). Coal, as a basic energy resource, is expected to continuously present long-term stability and maintain an irreplaceable position in the national economy. Rapid economic growth in China is largely dependent on coal as its main energy source (Xu et al., 2016). Under the condition that the current economy of China is declining, imbalance between coal supply and demand is prominent, and this disproportion continues for a long period. Coal prices also continue to fall with the high inventories and serious surplus of coal. Meanwhile, the coal consumption reduction caused by changes of industrial structure, energy intensity and energy mix exacerbated the excess capacity of the China's coal industry. (Tang et al., 2016), the Central Government has published the Guidance on Deepening the Reform of the Coal Market and has unified the dual-track pricing system for coal to solve the overcapacity in coal industry (Yang et al., 2016). Studying the causes of coal overcapacity, the formation mechanism of changes in coal production, and the optimization of relevant regulations is significant to the healthy and sustainable development of the coal industry of China under these circumstances. By establishing the formation mechanism of coal production capacity, this study investigates the capacity regulation of the coal industry, establishes an optimization model for capacity deregulation, and obtains an effective regulation and optimization scheme to guide the establishment of long-term stable relationship between coal supply and demand. Establishing such relationship can not only avoid large fluctuations in the coal market but also provide a theoretical basis for designing a government-related policy system. The remainder of this study is organized as follows. Section 2 reviews the related literature. Section 3 specifies the materials and methods. Section 4 describes the data and variables. Section 5 presents the evaluation results and discussion. Section 6 carries out scenario analysis. Finally, Section 7 discusses the results, summarizes the paper, and offers policy recommendations.

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2. Literature review

In the existing literature on overcapacity, some scholars explored the causes of overcapacity from institutional aspects. Among domestic scholars, Wang and Ju (2012) and Wang et al. (2014) found that the improper intervention of local governments leads to excessive investment, thus resulting in overcapacity. Geng et al. (2011) stated that the policy subsidies of local governments distort the prices of factor markets, thus depressing the investment cost and forming excess capacity. Gan et al. (2015) discussed the causes of overcapacity from a government official perspective and found that the impulse to expand capacity leads to the formation of overcapacity when the resource cost is reduced. Among the foreign scholars, Blonigen and Wilson (2010) analyzed the relationship between overcapacity and government subsidies in exports, and they argued that an important cause of overcapacity is excessive subsidies to exporters. Zhang et al. (2016a, 2016b, 2016c) concluded that government subsidies are one of the factors contributing to overcapacity in the wind and solar industries. Bossche and Gujar (2010) attributed overcapacity to excessive government intervention in microeconomics; they argued that the best solution to overcapacity is liberalizing private sector investment. Yuan et al. (2016) quantified the rational capacity and potential investment of coal power in China during the 13th Five Year Plan period (2016–2020), and they found that if all the coal power projects submitted for environmental impact assessment (EIA) approval were put into operation in 2020, overcapacity will reach 200 GW, which will cause disastrous consequences. Wang et al. (2016) proposed a system dynamic model to forecast the change of China's coal production capacity in three baseline scenarios, namely, usual scenario, policy regulation scenario, and strengthening policy scenario; they found that China's coal overcapacity will continue and face severe challenge in the future. Zhang et al. (2016a,b,c) established Hicks-neutral and Solow-neutral models respectively to assess the coal capacity, and found a reasonable range (89%-105%) for China's coal capacity utilization and overcapacity cordon (85%). Foreign scholars have focused on a market perspective when analyzing the causes of overcapacity and considered overcapacity as a normal product under market economy. Lin et al. (2007, 2010) found that enterprises in developing countries can easily form a social consensus on the prosperous prospects for national economy, which can lead to "investment tide" and overcapacity. Jiang and Cao (2009) and Jiang et al. (2012) argued that investment surges are actually caused by the investment subsidies of local governments during regional competition, which distort the results of business investment behavior. To the contrary, this phenomenon should not cause overcapacity, especially overinvestments on many industries under the background of Chinese transition.

Most scholars have analyzed the causes of overcapacity only from a single point of view or subjective judgment. Wang et al. (2015) analyzed the internal logic relationship among the causes of overcapacity in the coal industry of China from three levels. These three levels are pressure-driven behavior (corporate profit-driven behavior, local development impulse), state reflection (market supply and demand changes), and response measures (government administrative intervention, the central and local interests of the game). However, this analysis was only qualitative; in-depth quantitative analysis was not performed. Zhang et al. (2016a,b,c) explored the cause of coal overcapacity based on system dynamics but did not include government regulation as an important regulatory factor and thus failed to conduct a comprehensive study. Overall, the current analysis on the mechanism of coal production overcapacity has yet to form a complete logic framework. Existing studies present obvious flaws, such as the separation of government and enterprises, the neglect of market price mechanism, and the environment of supply and demand.

This study therefore conducts an in-depth quantitative analysis on the formation mechanism of coal production to explore the cause of coal overcapacity under the background of coal supply and demand environment, with construction industry development as the driving force, market price mechanism as guide, and government policies as control measures.

3. Materials and methods

3.1. Research framework

The formation of excess coal production capacity is due to structural reasons. The supply of coal products exceeds the demand under certain economic conditions, and the dramatic changes in the market generates cyclical fluctuations in market demand, resulting in decreased utilization of equipment and high degree of idle equipment in the coal industry. The weak demand for coal consumption reduces coal consumption, and the excessive pursuit of coal enterprises increases the investment capacity of the coal industry, and, thus, coal production continues to grow. The increasing coal production causes the imbalance of supply and demand in the coal industry to seriously hinder the healthy development of the industry.

The basic principle of supply and demand (Marx, 2004) indicates that the value determines the price, the price determines the supply and demand, supply and demand control prices, and prices constrain supply and demand. According to demand theory (Jorgensen, 1966), provided that other conditions remain unchanged, a commodity demand and its own price change in opposite directions, that is, the demand decreases as the price of the commodity rises and increases as the price of the commodity decreases. Changes in coal prices tend to affect changes in coal demand. Therefore, in exploring coal supply and demand relations must take full account of coal prices; the rise in coal prices will lead to lower coal consumption to a certain extent. Tobin's q theory is an investment theory of stock price and investment expenditure, and it is widely used in stock market investment analysis and helpful to analyze macroeconomic investment activities. Tobin's q theory is also based on the theory of cost and price, and the firm's profit behavior is the starting point, through which the relationship between asset market value and replacement cost determines investment efforts (He, 2010). For coal enterprises whose purpose is to profit, when the market value of coal products is determined to be higher than the cost of the products, these coal enterprises will continue to increase investment in coal production capacity to pursue profit maximization. The increase in production capacity due to increased capacity investment will stimulate an increase in coal supply.

The supply and demand imbalance of the coal industry caused by low consumption and high supply increases overcapacity. Coal enterprises not only did not limit and cut production but also were trapped in the "the more excess capacity, the more desperate to produce" vicious circle. The failure of this market situation makes the implementation of industrial policies, such as production capacity, imminent. "Market failure" theory implies that changing the market mechanism is not a panacea, as many shortcomings remain although the market mechanism is effectual. Industrial policies are mainly the remedy measures took by the government to address the problems caused by market mechanism.

The framework combs the internal logic relationship among the causes of coal production capacity in the coal industry of China from the perspectives of market supply and demand changes as well as central and local government administrative intervention based on the above theories. Relational and conductive feedback paths are constructed, and these paths reflect the relationship between coal production capacity and related factors.

The proposed model consists of four paths (Fig. 1), namely, (1) the transmission of the construction industry to the coal industry, (2) mechanism of coal production capacity investments, (3) the reduction of the backward production capacity mechanism, and (4) factors affecting coal production. Specifically, coal production capacity is the result of the new capacity over the years, the previous phase of the coal production capacity, and the accumulation of backward production

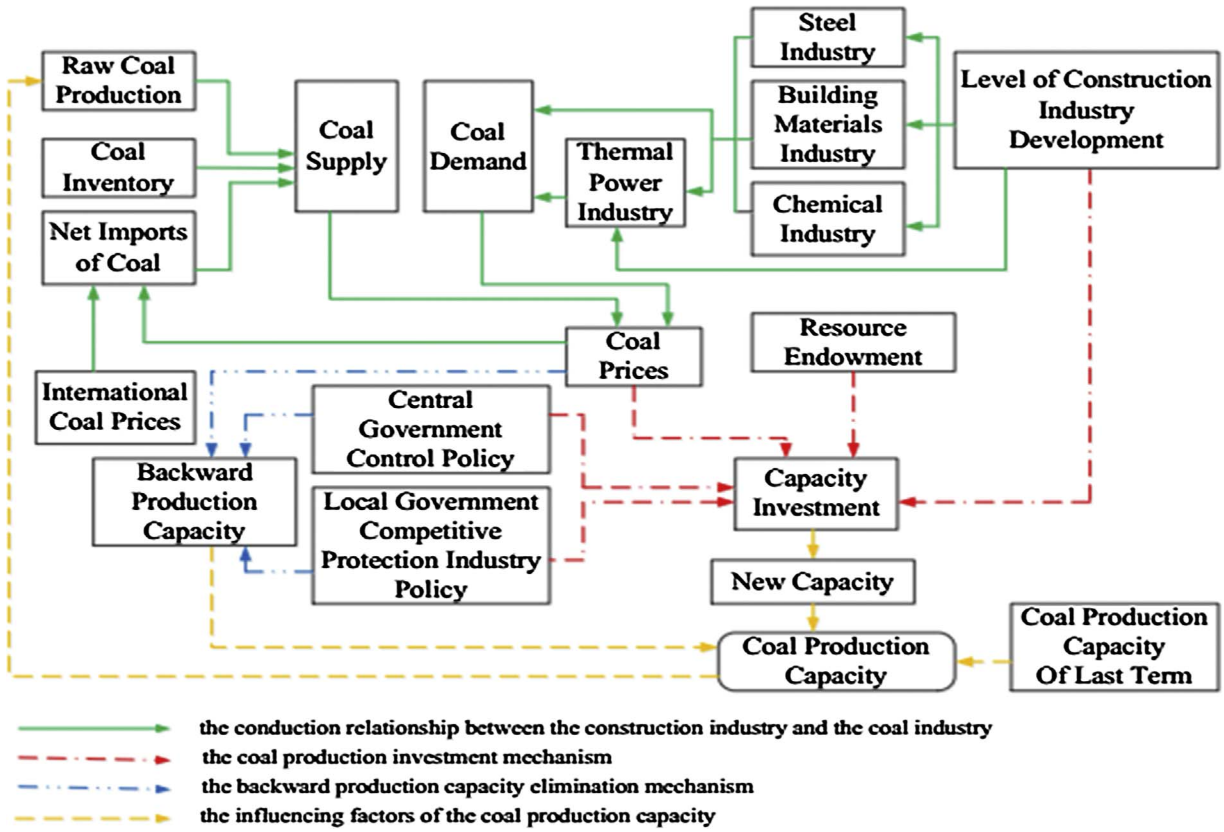

Fig. 1. Framework of coal production capacity formation mechanism model.

capacity. Under the influence of external factors, backward production capacity is mainly affected by the policy constraints made by central and local governments, and the survival-of-the-fittest, fully market-oriented competition in the coal industry is bound to generate low prices of coal, which affects the elimination of backward production capacity and a new round of capacity investments. Construction industry development exerts direct and indirect effects on coal production capacity investments and thus influences the new capacity of coal production. Coal overcapacity is inevitably transmitted to the downstream of the four major coal-consuming industries, creating a dynamic effect on these four industries and resulting in irrational expansion that reverses the effect of coal overcapacity. Changes in coal production capacity promote changes in coal production processes, thus leading to changes in the domestic coal production of China, which eventually affects the domestic coal market supply and demand and coal price fluctuations. The irrational investment behavior of coal enterprises and local governments transform ultimately into capacity investments and induce overcapacity, which constitute the cycle-loop formation mechanism of coal production. We have highlighted the four paths by using different types of line colors. (Fig. 1).

3.1.1. Conduction relationship between the construction industry and coal industry

The construction industry is one of the pillar industries of the national economy. Researches show that nearly 32% of global resources, 40% of global energy consumption and 25% of global carbon dioxide (CO_2) emissions are produced in the building sector. Its rapid development not only stimulates the related industries, such as the building material industry and real-estate industry, but also makes these related industries inhibit or promote their own development and form dynamic interactive forms. Qi et al. (2012) calculated the complete consumption coefficient of the construction industry and its backward related industries according to the input–output table of China in 2007. The steel rolling processing industry; thermal power production and supply industry; cement, lime, and gypsum manufacturing industry; coal mining and washing industry; synthetic material manufacturing industry; and other industries are the most closely related ones among 133 industries with complete correlation with the construction industry (Qi et al., 2012). The construction industry is related to iron and steel, building material, electricity, chemical, and other four coal-consuming industries and the coal industry itself. The production of the construction industry, as a basic industry, mainly serves as fixed assets in various industries. Production consumes considerable raw materials, manpower, and material resources, thereby exerting a highly sensitive, strong driving and pulling effect on backward related industries.

In the investment-driven economic growth model, investors increase investments on the construction industry based on the optimistic expectations on real estate and other industries; such increase in investments promote the optimistic expectations on steel, cement, building material, and chemical industries, advancing the development of four coal-consuming industries, and stimulating coal demand (Wang et al., 2013). The increases in coal demand of the main coal consumption industry play a positive role in pulling the domestic coal prices in China, which stimulates investment in coal production capacity and eventually leads to increased production capacity and industrial scale. The reality of the industry development rate is far less than expected. When the economic cycle enters a new normal, some difficulties are imposed in the investment sources in construction and demand cannot keep up with the supply, thereby resulting in a series of industry overcapacity.

The basic role of the construction industry makes it an important pillar industry in the national economy and a crucial force to promote economic and social development (Tan, 2014). The construction industry exerts a great correlation effect on the entire national economy and acts as an especially enormous driving force for the development of related industries. Therefore, this study explores the effect of the construction industry on its associated industries, that is, the four coal-consuming industries, and capacity investments based on the

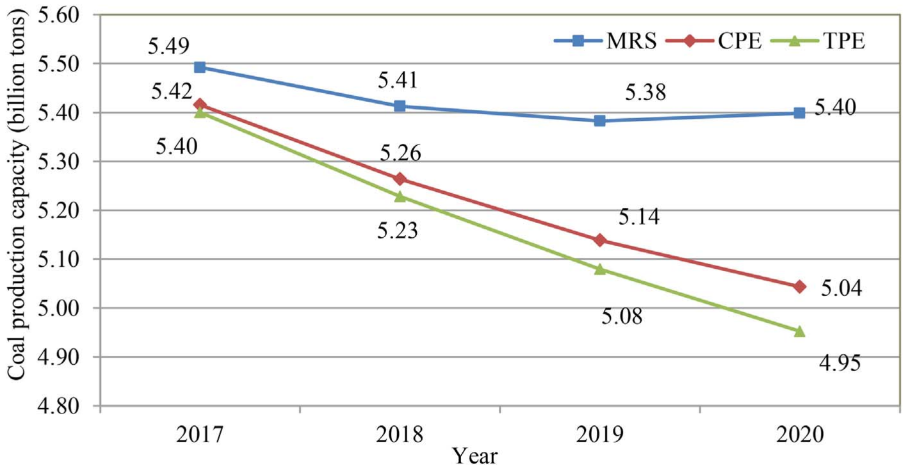

Fig. 2. Capacity change predictors for the scenario analysis in 2017–2020.

construction industry through quantitative methods. From the demand side, construction industry development is controlled through national economic industrial restructuring, transformation, and upgrading to promote sustainable and stable economic development as well as the rapid dissolution of overcapacity.

3.1.2. Influencing factors of coal production capacity investment

The existence of many uncertainties and high-risk characteristics and the length of coal production capacity investment project cycle that generally lasts for decades are inevitably affected by government-related industrial policies, coal prices, technology, and resource conditions (Zhang et al., 2013). In this study, the investment factors of coal production capacity are mainly from four aspects, namely, coal prices, resource endowments, government-related industrial policies, and the level of construction industry development. The central and local governments play different roles in the capacity investment process (Geng et al., 2015). The government-related industrial policies are specifically divided into two aspects, namely, central government regulation and control policies and local government competitive protection industrial policy.

3.1.2.1. Central and local government policies. Since the reform and opening up, the local governments of China play an important role in regional economic growth. They seek all possible investment opportunities to promote local economic development with extraordinary enthusiasm (Zhou, 2007). Under the existing institutional background, the local governments have adopted various preferential policies to attract investment and intervene in the investment of enterprises in pursuit of rapid economic growth. The main reason lies in the reform of fiscal decentralization and the promotion system of Chinese local government officials. In the early 1990s, Lantz and Junqueira-Lopez (1992) proposed that an enterprise's capacity scale is directly settled by its investment behavior and that certain types of investment (investment subsidies, if any) strongly stimulate the enterprise's investment behavior. Henderson and Cool (2003) and Yifu et al. (2010) also noted that overcapacity is caused by an enterprise's capacity expansion bandwagon behavior and that the curb on the enterprise's overinvestment can effectively eliminate overcapacity.

3.1.2.2. Coal prices. The law of economic value indicates that value determines the price. Coal prices directly reflect the changes in the value of assets in coal resource investment projects. Coal price rises along with the value of coal resource. By contrast, When the coal price increases, the value of coal resource investment projects reduces. Investors are bound to consider the price factor before making investment decisions; therefore, coal price positively affects capacity investment.

3.1.2.3. Level of construction industry development. The construction industry not only promotes the coal industry demand through the four coal-consuming industries and affects the coal production capacity investment indirectly but also directly affects coal production capacity investment as a basic industry. As a pillar industry, construction industry development requires the consumption of certain materials and equipment regardless of the size and manner of building, thus forming investment demand, and investment in fixed assets inevitably leads to the accelerated expansion of the investment scale (Jiangxi, 2004). Therefore, construction industry development is bound to stimulate coal production capacity investments. On this basis, this study selects the investment in fixed assets in the construction industry as an indicator of the level of construction industry development to explore how it affects coal production capacity investments.

3.1.2.4. Resource endowments. Natural resources are the foundation of economic development and the basic factor of regional economic growth. From its dynamic mechanism, economic growth depends not only on labor, material capital, human capital, and other socio-economic factor endowment but also on natural resource endowment (Xie et al., 2013). From the perspective of natural endowment theory, countries specialize in the production of different products based on geographical location, climate conditions, natural resources, and other different aspects as well as resource endowment to induce investors in making investment-oriented behavior. Resource endowment theory provides the orientation for the investment behavior of investors. High coal-consuming industries are likely to be located in regions with abundant coal resources (Song et al., 2016). Therefore, the abundance of mineral resources is one of the factors that concern investors before making capacity investments.

3.1.3. Influencing factors of backward production capacity

Backward production capacity is mainly defined from two aspects. Using the technical level of production as basis, the so-called backward production capacity refers to the production equipment, production processes, and other production capacity in which the technical level is lower than the industry average. Judging from the consequences of production capacity, that is, if pollutant emissions, energy consumption, water consumption, and other technical indicators of the production equipment and production technology are higher than the industry average, then the production capacity is backward production capacity. From this perspective, backward production capacity is a technical problem and refers to the technical level (including equipment and processes) in which the standard production capacity cannot meet the national laws and regulations and the industrial policy

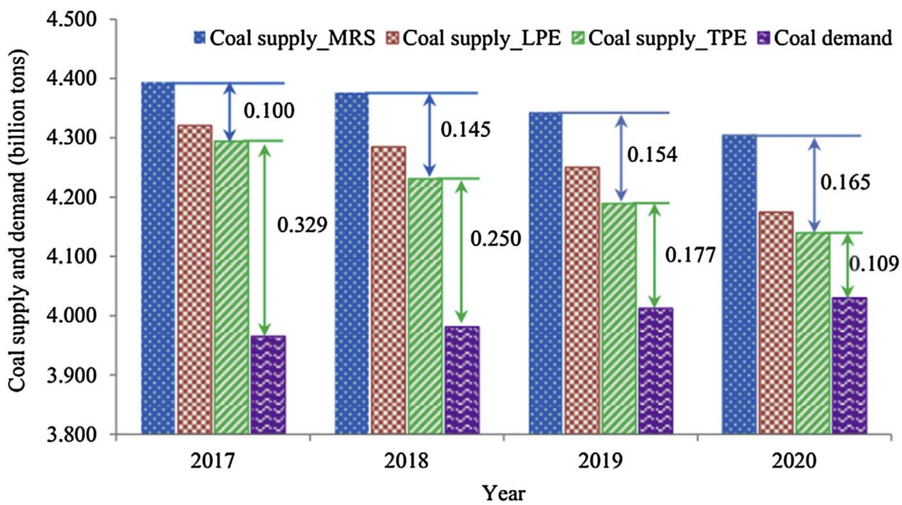

Fig. 3. Coal supply and demand predictors for the scenario analysis from 2017 to 2020.

established in specific practice.

The elimination of backward production capacity is mainly affected by government policies. Under the current situation of insufficient demand caused by the slow recovery of the national economy and backward production capacity, continuously operating coal enterprises have adopted the sales strategy with the price premium, which results in continuously decreasing coal prices. At present, supply and demand change and prices rebound slightly in the coal market under the conditions of strict control of production and illegal construction and strict implementation of production reduction. The tasks of cutting production, controlling the total amount, and stabilizing coal prices remain difficult in face of instability and uncertainty. The production factor prices of China are mainly based on administrative pricing and are below the market equilibrium level.

Enterprises do not assume corresponding responsibilities in the environmental protection, production safety, and social security, and local governments provide preferential or compensation for enterprises to attract investment in all aspects; the distortion of factor prices is serious, thus resulting in the weak market capacity to eliminate backward production capacity (Li, 2012). In the face of great pressure on energy conservation, emission reduction, and production capacity, the central government has issued a series of policies to eliminate backward production capacity, mainly including industrial access management, administrative compulsory elimination, economic restraint measures, incentive measures, and supervision of local governments in terms of assessment and accountability. However, the administrative methods implemented by the central government to eliminate backward enterprises show that the mechanism to protect backward enterprises objectively exists in the market economy of China. First, the market imperfect competitive behavior is observed via the external, administrative monopoly, government subsidies, and factor price distortions. Second, as long as the benefits outweigh the costs and the probability of local government irregularities is small, or if the probability of discovery is large but the intensity of punishment is small, local governments protect these low-cost, low-tech backward enterprises (Liang, 2008). Therefore, the central and local governments influence the elimination of backward production capacity during common-interest game.

3.1.4. Factors affecting coal production capacity

The coal industry is a capital-intensive industry, and its production capacity changes depending not only on the new capacity changes, but also on the elimination of backward production capacity. Therefore, the coal production capacity is divided into three parts in this study, namely, the existing production capacity of enterprises, which is the ability to check within the period, that is, the remaining capacity of the last period; the new capacity; and the out of backward production capacity. New production capacity can be the ability of previous infrastructure or technological transformation projects to be formed during the current year as well as the increased capacity made by enterprises through management tools and capacity investments. Current coal production capacity is equivalent to the end of last period of the coal production capacity, coupled with the new capacity created by current period of business through capacity investment minus the current phase out of backward production capacity. The change in coal production capacity leads to the fluctuation in coal production through various links of production and to the fluctuation in coal output. The imbalance between coal supply and demand results in changes in the coal market supply and demand and the relative decline in the price of excess coal. Coal prices in the four major coal-consuming industries are not significantly affected by the downward pressure. Coal price fluctuation, level, and trend directly determine the market expectation and stimulation of coal enterprises and local governments to invest in the coal industry. Investment behavior on coal enterprise, the final transmission to the capacity, and the formation of cycle capacity of the process vary. The coal consumption of the four major coal-consuming industries is insignificant under the economic downward pressure, which affects coal price and leads to coal price fluctuations. The price level and variation trend directly determine the market expectations of coal enterprises and local governments on coal industry investment and stimulate changes in the investment behavior of coal enterprises. Finally, they transmit to the capacity changes leading to the formation of cycle capacity.

3.2. Method

The coal market of China is complex and involves many economic variables. All economic variables are interdependent and causal. The single equation model cannot accurately describe the economic phenomenon of interdependence.

Kelejian and Prucha (1998, 1999) and Caner and Hansen (2004) and Ping Yu (2013), Dhrymes (1969), Lee (2007) investigated the two-stage least squares (2SLS), three-stage least squares (3SLS), quasi-maximum likelihood (QML) and generalized method of moments (GMM) estimation methods. Simultaneous equation models (SEM) have traditionally been used in the economic world; they are used presently in many different fields. Examples can be found in econometrics, medicine, and even the relationship between labor force participation and health and educational attainment. Chen et al. (2011) employed SEM to describe the interactions among a set of variables, such as economic growth, foreign trade, FDI, and environmental pollution. Omri (2013) examined the nexus between CO2 emissions, energy

Table 1
Model variable explanation.

Endogenous variable	Variable symbol	Metric name	Unit
Coal supply	*LNS(S)*	Coal supply	Million tons
Coal demand	*LNDE(DE)*	Coal demand	Million tons
Raw coal production	*LNRP(RP)*	Raw coal production	Million tons
Net imports of coal	*LNNIC(NIC)*	Net imports of coal	Million tons
Thermal power industry	*LNFE(FE)*	Thermal power generation	100 million kWh
Steel industry	*LNCS(CS)*	Crude steel production	Million tons
Building material industry	*LNCP(CP)*	Cement production	Million tons
Chemical industry	*LNMP(MP)*	Refined methanol production	Million tons
Coal prices	*LNCCPI*	China coal price index	
Backward production capacity	*LNEBPC(EBPC)*	Backward production capacity—eliminated	Million tons
Capacity investment	*LNICMW*	Investment in fixed assets in coal mining and washing	Billion
New capacity	*LNNC(NC)*	New coal production capacity	Million tons
Coal production capacity	*LNCPC(CPC)*	Coal production capacity	Million tons

Exogenous variable	Variable symbol	Metric name	Unit
Coal inventory	*INB*	Balance at the end of the year	Million tons
Level of construction industry development	*LNIACI*	Investment in fixed assets in the construction industry	Billion
International coal prices	*LNBJ*	Australia BJ thermal coal index	
Central government control policy	*CGPIAP*	Central government promoting capacity investment policy	
	CGPIAN	Central government restraining capacity investment policy	
	CGPCA	Central government eliminating backward production capacity policy	
Local government competitive protection industry policy	*LGPIAP*	Local government promoting capacity investment policy	
	LGPIAN	Local government restraining capacity investment policy	
	LGPCA	Local government eliminating backward production capacity policy	
Resource endowment	*LNRE*	Proven coal reserves	Billion tons

consumption, and economic growth using SEM with panel data comprising 14 MENA countries over the period of 1990–2011. Adewuyi and Awodumi (2017) employed SEM to investigate the relationship among biomass energy consumption, economic growth, and carbon emissions in West Africa from 1980 to 2010. 2SLS is limited-information method that considers one equation at a time. The advantage of limited-information methods is that they can be used in SEM with not all the equations identified (equations that can be solved), and, in particular, 2SLS can be used with all types of identified equations. Thus, 2SLS is one of the most used methods for SEM.

Therefore, this study selects the simultaneous equation model to describe the complex dynamic relationships among the variables in the coal market. After the natural logarithmic transformation of the variables other than the policy to eliminate heteroscedasticity, SEM is constructed with the following equations: Eqs. (1)–(4) reflect the influence of the development level of the construction industry on the four coal consumption sectors and the link between the four coal consumption industries. Eq. (5) reflects the influence of coal prices, the development level of the construction industry, government policies, and resource endowments on capacity investment. Eq. (6) reflects the influence of capacity investment on new capacity, and Eq. (7) denotes the influence of coal prices and central and local policies on the elimination of backward production capacity. Eq. (8) reflects the change in coal production due to changes in coal production capacity. Eq. (9) reflects the influence of coal prices at home and abroad on net imports of coal, and Eq. (10) denotes the influence of coal supply and demand on coal prices. Eqs. (11)–(13) are constant equations, representing coal supply, coal demand, and the formation of coal production capacity, respectively.

$$LNFE_t = \alpha_1 LNCS_t + \alpha_2 LNCS_{t-1} + \alpha_3 LNCP_t + \alpha_4 LNCP_{t-1} + \alpha_5 LNMP_t + \alpha_6 LNMP_{t-1} + \alpha_7 LNIACI_t + \alpha_8 LNIACI_{t-1} + \mu_{1t} \quad (1)$$

$$LNCS_t = \beta_0 + \beta_1 LNIACI_t + \beta_2 LNIACI_{t-1} + \mu_{2t} \quad (2)$$

$$LNCP_t = \gamma_0 + \gamma_1 LNIACI_t + \gamma_2 LNIACI_{t-1} + \mu_{3t} \quad (3)$$

$$LNMP_t = \delta_1 LNIACI_t + \delta_2 LNIACI_{t-1} + \mu_{4t} \quad (4)$$

$$LNICMW_t = \varphi_0 + \varphi_1 LNCCPI_t + \varphi_2 LNIACI_t + \varphi_3 CGPIAP_t + \varphi_4 CGPIAN_t + \varphi_5 LGPIAP_t + \phi_6 LGPIAN_t + \phi_7 LNRE_t + \mu_{5t} \quad (5)$$

$$LNNC_t = \rho_0 + \rho_1 LNICMW_t + \rho_2 LNICMW_{t-1} + \mu_{6t} \quad (6)$$

$$LNEBPC_t = \lambda_1 LNCCPI_t + \lambda_2 CGPCA_t + \lambda_3 CGPCA_{t-1} + \lambda_4 LGPCA_t + \lambda_5 LGPCA_{t-1} + \mu_{7t} \quad (7)$$

$$LNRP_t = \sigma_1 LNCPC_t + \mu_{8t} \quad (8)$$

$$LNNIC_t = \phi_0 + \phi_1 LNCCPI_t + \phi_2 LNBJ_t + \mu_{9t} \quad (9)$$

$$LNCCPI = \theta_1 LNS_t + \theta_2 LNDE_t + \mu_{10t} \quad (10)$$

$$DE_t = FE_t + CS_t + CP_t + MP_t \quad (11)$$

$$S_t = RP_t + INB_t + NIC_t \quad (12)$$

$CPC_t = CPC_{t-1} + NC - EBPC_t$ (selecting 2006 as the beginning of production capacity) (13)

In the above formulas, the subscript t represents the year. LNFE (FE), LNCS (CS), LNCP (CP), and LNMP (MP) represent the thermal power generation, crude steel production, cement production, and refined methanol production, respectively. LNIACI stands for the construction industry development. LNCCPI is the comprehensive coal price index of China. LNBJ is the international coal price. LNICMW is the capacity investment. CGPIAP and CGPIAN represent the relevant promotion and inhibition policies made by the central government to promulgate the production capacity investment, respectively. LGPIAP and LGPIAN represent the relevant promotion and inhibition policies made by local governments to promulgate the production capacity investment, respectively. CGPCA and LGPCA represent the policies that the central government and local governments promulgate in out of backward production capacity, respectively. LNRE is the resource endowment. LNEBPC (EBPC) is the backward production capacity. LNNC (NC) is the new capacity. LNNIC (NIC) is the coal net imports. LNRP

Table 2
Policy quantitative criteria.

Index	Score	Criteria for judgment
Policy power *P*	5	Laws promulgated by the National People's Congress and its Standing Committee
	4	Ordinance promulgated by the State Council, orders by the Department of Homeland Ministry
	3	Interim Regulations promulgated by the State Council, regulations by Department of Homeland
	2	The views of various departments, methods, the Interim Provisions
	1	notice
Policy goal *G*	5	"Must," "clear," "no," "strict control," and the strongest and most detailed description
	4	"Not less than/over," "strict use," and other strong tones of detailed description
	3	"According to not less than," "full use," and other strong tones of description
	2	"Under the premise of … …," "perfect," and other conditions of general description
	1	"According to," "to strengthen," and other general descriptions
Policy measure *M*	5	Specific measures are listed, and strict enforcement and control standards are given for each item with specific instructions
	4	Specific measures are listed, and detailed implementation and control criteria are given for each item
	3	More specific measures are listed, providing a general outline of the implementation from a number of perspectives
	2	Lists some basic measures and gives a brief implementation of the content
	1	There is no specific operational program, only from the macro talk about relevant content

(RP) is the raw coal production LNCPC (CPC) is the coal production capacity. LNS (S) and LNDE (DE) represent the coal supply and demand, respectively. INB represents the coal stocks. β_0, γ_0, φ_0, ρ_0, ϕ_0 represent the individual fixed effect of Eqs. (2), (3), (5), (6), and (9), respectively which do not change with time; μ_{1t}, μ_{2t}, $\cdots$, μ_{10t} are the corresponding random error terms, which obey zero mean and variance-bounded normal distribution; Eqs. (11)–(13) are the identity equations, which represent the coal supply, coal demand, and coal production, respectively.

4. Data and variables

This study establishes a simultaneous equation system to comprehensively investigate the formation mechanism of coal production capacity, seek the root causes of overcapacity, and eventually provide concrete basis for the effective solution of overcapacity. The system includes the level of construction industry development, capacity investment, backward production capacity, the central and local industrial policies, and coal supply demand. The annual data from 2006 to 2014 are selected for analysis. The data are mainly from China Wind Information, China Industrial Statistical Yearbook, China Energy Statistical Yearbook, and China Statistical Yearbook. Table 1 lists the model variables.

4.1. Coal demand

From the coal demand structure of China, electricity, steel, building material, and chemical industries are the main coal-consuming industries (Wang and Li, 2008). In this study, the coal consumption of thermal power, steel, building material, and chemical industries is selected as coal demand (Wang et al., 2013). Coal continues to account for more than 90% in the thermal power generation; thus, this study selects the thermal power generation as the thermal power industry coal demand (Wang and Li, 2008). The main products of the building material industry are cement, flat glass, building ceramics, sanitary ceramics, various wall materials, and chemical materials. Cement production, which accounts for a large proportion, is selected as the coal demand of the building material industry (Wang and Li, 2008). Methanol is an important chemical product and raw material, and its proportion in the chemical industry is gradually increased. Coal liquefaction, coal alcohol, and other alternative liquid fuels will be the growth points of demand for chemical coal in the future. Therefore, fine methanol production is selected as the chemical industry coal demand (Wang and Li, 2008). Coal dominates the energy consumption structure of the iron and steel industries of China. The coal demand for the iron and steel industries is mainly determined by pig iron production, crude steel production, and energy consumption. The proportion of crude steel production is larger than that of pig iron production. Therefore, this study selects crude steel output as the coal demand of the iron and steel industries (Chen et al., 2015).

4.2. Coal supply

This study selects the net import of coal, the beginning of the end of the year inventory balance, and production to calculate coal supply according to China Statistical Yearbook.

4.3. Level of construction industry development

In this study, the investment in fixed assets of the construction industry is selected as the evaluation standard of the level of construction industry development. Investment, export, and consumption are the three carriages driving economic growth. The economy of China remains at the initial stage of development, and economic growth features typical characteristics of pulling. Economic development needs to stimulate investment demand, and the formation of the final consumer demand depends on increasing investment. The rapid growth of the national economy is inseparable from the continued growth of investment. Investment in fixed assets is an important part of the total social demand. The construction industry included in the secondary industry, the materials and equipment consumed in the production, and the construction process stimulate the investment demand and promote the expansion of investment scale.

Therefore, the fixed asset investment in the construction industry is a comprehensive index reflecting the investment scale and speed of fixed assets in the construction industry. This study selects the fixed asset investment of the construction industry to represent its level of development to explore the corresponding influence on capacity investment.

4.4. Domestic and international coal prices

In this study, the coal price index of China represents the domestic coal prices, and the Australian BJ thermal coal index denotes the international coal prices. The coal market price index is formed by the China Coal Market Network through integrating all aspects of information and systematic collection of coal market price data, which can reflect the situation of the national coal market prices. Therefore, the China coal price index is selected to reflect the coal price variables (Yang, 2006). By integrating various aspects of information, the system collects coal market price data and orders the formation of the coal market price index. Given that the Coal Price Index of Australia is linked to the Coal Price Index of the Inter-Continental Exchange and the Global Coal Electronic Trading Platform, it has also become an

Table 3
Unit root test.

Variable	Inspection form	ADF test value	P values	Conclusion
LNFE	(c,0,1)	−3.127406	0.0701	Smooth
LNCS	(c,0,1)	−4.823281	0.0098	Smooth
LNCP	(c,0,1)	−3.297623	0.0638	Smooth
LNMP	(c,0,1)	−4.039174	0.0235	Smooth
LNIACI	(0,0,1)	−2.057472	0.0470	Smooth
LNCCPI	(c,t,1)	−14.21944	0.0013	Smooth
LNICMW	(0,0,1)	−1.643693	0.0927	Smooth
CGPIAN	(c,0,1)	−3.038572	0.0848	Smooth
CGPIAP	(c,0,1)	−4.289522	0.0224	Smooth
LGPIAN	(c,0,1)	−5.409045	0.0078	Smooth
LGPIAP	(c,0,1)	−17.54670	0.0000	Smooth
CGPCA	(0,0,1)	−3.650657	0.0049	Smooth
LGPCA	(0,0,1)	−5.367754	0.0013	Smooth
LNRE	(c,0,1)	−3.133303	0.0765	Smooth
LNEBPC	(0,0,1)	−1.895409	0.0613	Smooth
LNCPC	(0,0,1)	−2.375481	0.0278	Smooth
LNS	(0,0,1)	−5.086280	0.0006	Smooth
LNDE	(0,0,1)	−4.214195	0.0241	Smooth
LNNC	(0,0,1)	−2.232633	0.0338	Smooth
LNNIC	(0,0,1)	−2.325135	0.0287	Smooth
LNRP	(0,0,1)	−1.825061	0.0688	Smooth

important reference for future negotiations and spot negotiations to guide coal price basis, so the data are authoritative (Li et al., 2012).

4.5. Backward production capacity

Currently available data on the elimination of backward production capacity are from the beginning of 2011. This study provides the 2006–2010 data with the standard of 0.1 billion tons/year.

4.6. New capacity

This study obtains new capacity data from the wind information.

4.7. Coal production capacity

The coal production capacity in this study is mainly based on the following formula:

t year coal production capacity = t–1 year coal production capacity + t year new coal production capacity − t–1 year coal production capacity × year backward production capacity out of rate (year backward production capacity out of rate = 2.773%).

4.8. Resource endowment

The existing literature uses the following indicators to represent the resource endowments: the proportion of employees in the extractive industry in the total number of local population (Fang et al., 2011); the proportion of employees in the extractive industry to industrial employees (Jing and Wang, 2008); the mining industry practitioners accounted for the proportion of social workers (Han, 2014); fixed asset investment in the extractive industry accounting for the proportion of total investment in fixed assets (Xu and Wang, 2006; Hu and Xiao, 2007); the proportion of the employees in the extractive industry to the total income of the local employees (Ding and Deng, 2007); the proportion of energy industrial output value to total industrial output value (Shao and Qi, 2008); and coal, oil, and natural gas reserves weighted representation of resource abundance (Zhang and Liang, 2010). This study draws on the index of resource abundance by Zhang and Liang (2010) and selects the proven reserves of coal resources to represent the resource endowments, combining with the research theme.

4.9. Government policy (CGPIAP, CGPIAN, LGPIAP, LGPIAN, CGPCA, LGPCA)

China's coal industry reform is led mainly by the government, with government policy as the main external guiding force. The government's radical mining policy overtly encouraged all sizes of mines to provide much-needed energy for the country in the early 1980s (Gunson and Yue, 2002; Andrews-Speed et al., 2003; Shen et al., 2009; Yu et al., 2014; Cao, 2017). The central government conducted two major initiatives (i.e., mine closure and production reduction campaign and coal resource consolidation campaign) in response to internationally touted sustainability between the late 1990s and mid-2011. In recent years, China has strengthened the structural reform of the supply side, adopted five measures to strengthen the macro-control and market supervision, paid more attention to the use of market mechanism, economic means and the rule of law to resolve excess capacity in the face of the serious overcapacity of coal production capacity, and increased policy efforts to guide the capacity to withdraw from the initiative especially in the steel, coal and other industries. Therefore, this study selects government policies as exogenous variables.

In view of the difficulty in local coal-related policies, this study selects Shanxi, Shaanxi, Guizhou, Anhui, Shandong, Henan, Jiangsu, Inner Mongolia, Yunnan, and Jiangxi as province representatives, as well as collects and collates the relevant policies in the past 10 years. Local government policies are mainly collected through official websites and statistical offices in various provinces. Policies issued by the central government are mainly collected through the Global Law Network and related websites. This study focuses on investment promotion and investment inhibition to better subdivide the role of policy.

According to the methods of quantitative research (Ji and Wu, 2015; Peng et al., 2008; Liu et al., 2014), this study selects policy strength, policy measure, and policy target as three analysis dimensions to reflect the policy content validity comprehensively and ensure that the policy variable obtains accurate expression. The single annual policy score is expressed as

$$PMG_i = \sum\nolimits_{j=1}^{n} (g_j + m_j) p_j, \tag{14}$$

where i is the published year of the scoring policy; n is number of policies issued in $i$year; J is the jth policy promulgated in j year; & tpcheck;$g_j + m_j$ & tpcheck;is the score of policy measure and policy goal of the jth policy; $p_j$is the power of the jth policy; and $PMG_i$is the overall status of policy power, policy goal, and policy measure in year i. The real situation is often the cumulative effect of all relevant policies until the end of the corresponding year; hence, the cumulative effect of the policy must be calculated. The cumulative annual score for the policy, which is the policy intensity index, is

$$NPMG_i = \sum\nolimits_{k=c}^{i} PMG_k, \tag{15}$$

where $NPMG_i$ is the policy power in year i, k is the year of PMG, and c is the initial year of the study. In this study, c = 2006. Considering the time limit of the policy, adjusting the scores during calculation and removing the expired policies in the calculation of next year's score are necessary to make the results realistic. Table 2 explains the policy quantitative criteria.

5. Result analysis

5.1. Stationary test of variables

Non-stationary economic time series tend to show a common variation trend; direct estimation often leads to "pseudo-regression" or "false regression" phenomenon. The Augmented Dickey-Fuller (ADF) method for assessing the stability of time series variables tests the process (Dickey and Fuller, 1979). The lag order is determined according to the Schwartz criterion (Gao, 2009). The results show that all

Table 4
Endogenous test results.

	Eq. (1)	Eq. (2)	Eq. (3)	Eq. (4)	Eq. (5)	Eq. (6)	Eq. (7)	Eq. (8)	Eq. (9)	Eq. (10)
resid	0.144	0.378	0.181	0.314	0.298	0.423	0.192	0.177	0.214	0.131
	(0.026)	(0.000)	(0.046)	(0.000)	(0.000)	(0.000)	(0.023)	(0.042)	(0.005)	(0.000)
R^2	0.975	0.998	0.989	0.992	0.989	0.999	0.974	0.968	0.972	0.964
Adj-R^2	0.964	0.982	0.980	0.973	0.978	0.992	0.962	0.954	0.969	0.947

time series can meet the requirement of sequence stability, and the t statistic is less than 10% critical value (Table 3).

5.2. Endogeneity of the model

This study uses many variables, and a causal relationship exists between the variables. Only single equation can lead to the endogeneity of the variables and subsequently to positive and nonconforming results. To determine whether the variables are interdependent, a variable endogeneity test is needed to test the continuity of the equation. The commonly used test method is the Hausman test. Through the auxiliary regression of all the exogenous variables of the entire system, the residual value is obtained, which is $resid_i(i = 1, 2, \cdots, 10)$. The residual value is then introduced into the corresponding equation through the significance of the residual value to determine the endogeneity and then test the continuity of the equation. Table 4 lists the results.

Judged at 5% significance level, the resid coefficient is not significantly 0; thus, the simultaneous equations pass the Hausman endogeneity test, and the complex dynamic relationship between various variables in the coal market should be reflected by the SEM.

5.3. Model identification

For any equation in the SEM, the necessary condition to be recognizable is $G–1 \le M_i$, $M_i = (G + K)\text{-}(g_i + k_i)$, where G is the number of endogenous variables of the simultaneous equation, K is the number of prerequisite variables in the joint model, and g_i,$k_i$are the number of the endogenous variables and precedent variables that appear in the ith equation. According to the above simultaneous equations, $G = 13$ and $K = 15$ for Eq. (1), $g_1 = 3$ and $k_1 = 3$, then $M_1 = (13 + 15)\text{-}(3 + 3) = 22$, and $G–1 = 14–1 = 13 < 22$. Therefore, Eq. (1) can be identified and is over-identified as well as be used to identify the remaining equations. The results show that all equations can be identified.

5.4. Analysis of the estimation result of the system of equations in simultaneous equations

The order and rank conditions of the two equations are both true and overprotective. Two-stage least squares (2SLS) is the most important parameter estimation method for overestimated simultaneous equations, because it overcomes the shortcomings of the indirect least squares method for over-identified structural equations and the tool. This study uses EViews 8.0 software package to test and analyze the model based on W2SLS test method.

Table 5 summarizes the results of the system of equations under simultaneous equations. This study explores the effects of the changes in the level of domestic construction industry development on the four major coal-consuming industries and then on the changes in coal production capacity. By analyzing relevant factors, this study finds the cause of serious excess of coal production capacity.

5.4.1. Quantitative analysis on the relationship between the level of construction industry development and the change of coal industry demand

As the four major coal-consuming downstream industries, thermal power, steel, building material, and chemical industries account for nearly 80% of coal consumption. The industries at the end of coal consumption are mainly infrastructure and real estate. Real estate, as a basic industry of the construction industry, provides the necessary intermediate products and promotes construction industry development. The production and construction of the construction industry forms the fixed assets of the society, which lays the foundation for the expansion and reproduction of the real estate industry and the intermediate consumption, and then promotes sustainable construction industry development. The level of development of the four simultaneous equations, that is, thermal power, steel, building material, and chemical industries, as well as the construction industry, show that the basic construction industry plays a clear and sustained positive role in promoting the development of the four major coal-consuming industries. According to the results, the lagged construction industry greatly influences the development of thermal power, steel, building material, and chemical industries. The lagged investment in fixed assets increased by 1% increases thermal power generation by 0.018%, crude steel production by 0.336%, cement production by 0.299%, and refined methanol production by 1.097%. This growth indicates that the current construction industry development exerts a stimulating effect on the current period and the next phase of the construction industry-related materials based on good market expectations as well as the associated industries that are inclined to increase the production efforts for the construction industry, thereby providing more steel, cement and, other building materials. Based on good market expectations, the intensity of production to related industries is inclined to increase, providing additional reinforcement for the construction industry, such as cement and other building materials. The development of the current and the lag phase of the other three coal-fired industries positively influence current thermal power generation, current cement production, and refined methanol production, indicated by 1% increase. The current thermal power increases by 4.022% and 0.329%, lagged crude steel production by 1%, and thermal power generation by 0.21%.

5.4.2. Quantitative analysis on the causes of investment in coal

The “surge phenomenon” caused by economies of scale in the coal industry, the development impulse of the local governments under the guidance of GDP, and the excessive investment and management of the coal industry allow capacity investment to be blindly optimistic. This phenomenon then leads to increased overcapacity, coupled with changes in market supply and demand uncertainty as well as lack of a perfect market mechanism for adjustment. “Tide phenomenon” promotes the downstream power, real estate, and other related industries that place a large number of social capital into the market based on the future investment return, and the construction industry bear the brunt. From the results of simultaneous equations, the level of construction industry development positively influences capacity investment. Considering the investment in coal production capacity, every 1% increase in investment in fixed assets in the current period of construction industry increases the investment in coal production capacity by 1.099%, thereby indicating that the current construction industry greatly influences the capacity investments on the coal industry. When construction industry development is well, it stimulates the enterprises to invest more capital into the market and increase the investments on production capacity. However, when construction industry

Table 5
W2SLS simultaneous regression analysis

Model	*LNFE*	*LNCS*	*LNCP*	*LNMP*	*LNICMW*
C		7.834892***	8.263797***		3.412729***
		(0.234224)	(0.177109)		(5.51E-13)
LNCS	−2.563653***				
	(5.20E-13)				
LNCS(-1)	0.209622***				
	(2.23E-13)				
LNCP	4.022102***				
	(6.82E-13)				
LNCP(-1)	−0.905513***				
	(3.32E-13)				
LNMP	0.329058*** (9.00E-14)				
LNMP(-1)	−0.017048***				
	(5.31E-14)				
LNIACI	−0.496135***	0.082797	0.201774*	−0.332422	1.099462***
	(7.59E-14)	(0.132199)	(0.099962)	(0.278458)	(2.84E-14)
LNIACI(-1)	0.018299***	0.335827***	0.298790***	1.226208***	
	(1.06E-13)	(0.120054)	(0.090779)	(0.252876)	
LNCCPI					1.230389***
					(3.75E-14)
CGPIAN					−0.038432***
					(1.37E-15)
CGPIAP					0.002920***
					(8.93E-16)
LGPIAN					0.059428***
					(1.57E-15)
LGPIAP					−0.015018***
					(4.34E-13)
LNRE					2.811077***
					(1.67E-13)
R-squared	1.000000	0.971517	0.987914	0.975529	1.000000
Adjusted R-squared		0.960124	0.983080	0.965741	

Model	*LNNC*	*LNEBPC*	*LNRP*	*LNNIC*	*LNCCPI*
C	5.844502***	1.037054***	9.711119***	−91.94384**	
	(1.032918)	(0.368150)	0.291228	(36.84532)	
LNBJ				−14.59402*	
				(7.926652)	
LNCCPI		−0.244502***		32.43494***	
		(0.066774)		(10.67077)	
LNCCPI(-1)					
LNICMW	1.119983**				
	(0.420101)				
LNICMW(-1)	−0.573471*				
	(0.337964)				
CGPCA		0.001535**			
		(0.000509)			
CGPCA(-1)		0.000475 (0.000813)			
LGPCA		−0.002628***			
		(0.000806)			
LGPCA(-1)		0.004306***			
		(0.001446)			
LNCPC			0.841999***		
			(0.081005)		
LNS					−2.162956**
					(1.032670)
LNDE					2.596645**
					(1.104566)
R-squared	0.724888	0.988105	0.931060	0.545549	0.463068
Adjusted R-squared	0.614843	0.958367	0.919570	0.363768	0.372619

Note: The values in parentheses are the standard error of the estimates; ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

development slows down, the enterprises reduce their investment.

In addition, with the rise in coal prices, coal enterprises acquire good prospects for future industrial prospects, increase investment capital, and expand capacity investment. Therefore, coal prices positively influences capacity investments. Each 1% increase in resource endowment brings 2.811% increase in investment in fixed assets in coal mining and washing, thereby indicating that resource endowment and capacity investment show the same trend, and the three positive changes in capacity investment bring a positive impetus.

The study analyzes production capacity investment from central and local governments promoting and inhibiting capacity investments. The results of the investment capacity equation show that the restraining and pro-industrial policies of the central government exert corresponding effects on capacity investments. For Each 1% increase in the strength of the restraining policy, enterprises reduce their investment by 0.038%, and when the intensity of the promotion of industry policy

Table 6
The parameters set of different scenario.

change rate	Scenario	2015	2016	2017–2020
ω_1(%)	*MRS*	7	7	7
	CPE/TPE	−90	−90	−60
ω_2(%)	*MRS*	29	29	29
	CPE/TPE	30	30	10
ω_3(%)	*MRS*	90	90	−20
	CPE/TPE	110	110	−5
ψ_1(%)	*MRS/CPE*	10	10	10
	TPE	−20	−20	−10
ψ_2(%)	*MRS/CPE*	21	21	21
	TPE	25	25	8
ψ_3(%)	*MRS/CPE*	70	70	−30
	TPE	80	80	−10
τ(%)	*MRS/CPE/TPE*	20	8.3	7.64
ξ(%)	*MRS/CPE/TPE*	−6.52	−6.52	−7
ς(%)	*MRS/CPE/TPE*	−4	−4	−4
υ(%)	*MRS/CPE/TPE*	0	0	0

Note: According to the change of exogenous variables in market regulation scenario (MRS), central policy strengthening scenario (CPE) and two-level government policy strengthening scenario (TPE). $\omega_1$indicates the change rate of intensity of central government promoting capacity investment policy; $\omega_2$indicates the change rate of intensity of central government restraining capacity investment policy; $\omega_3$indicates the change rate of intensity of central government eliminating backward production capacity policy; $\psi_1$indicates the change rate of intensity of local government promoting capacity investment policy; $\psi_2$indicates the change rate of intensity of local government restraining capacity investment policy; $\psi_3$indicates the change rate of intensity of local government eliminating backward production capacity policy; τindicates the change rate of level of construction industry development; ξindicates the change rate of coal inventory; ςindicates the change rate of resource endowments; υindicates the change rate of international coal prices.

increases by 1%, enterprises increase their investment by 0.003%. The results also show that the effect of inhibiting policy is obviously greater than the effect of promoting policy; with the emergence of overcapacity, the central government has intensified its efforts to limit investment in production capacity to fundamentally resolve overcapacity.

The result of the equation shows that every 1% increase in the intensity of the promoting policy of the local governments reduces the investment of enterprises by 0.015%, and enterprises increase their investment by 0.059% for each 1% increase in the intensity of inhibiting policy of the local governments. This reverse effect can be explained from two aspects. First is the lag effect of policy implementation, and second is the introduction and issuance of restraining industry policy by the central government that will take considerable time; thus, central and local effects appear opposite. However, local governments have not effectively followed up the policy of restricting investments by the central government. Although local governments have responded to the policy of the central government, these governments retain blind investment in their need for regional economic growth.

5.4.3. Analysis of the causes of backward production capacity

From the model results, coal prices and the reduction of the backward production capacity show the same trend. For each 1% increase in coal prices, the reduction of the backward production capacity grows by 1.08%. The policy by the central government for eliminating backward production capacity can produce effective results in the current and next periods, but the coefficient size shows slight effect mainly because of the low degree of policy refinement, and the specific implementation process faces difficulties. Local government policies to eliminate backward production capacity fail to achieve the desired effect, and the policy effect is highlighted in the next issue. As policy strength increases by 1%, out of backward production capacity increases by 0.006%, because policy implementation requires a corresponding buffer time.

The policy on eliminating backward production capacity introduced by local governments cannot produce the corresponding effect. On one hand, local governments are in pursuit of GDP. Excessive implementation of the policy to reduce production capacity can lead to decline in investments and regional economy, thus preventing local governments from fulfilling the policy of eliminating production capacity. On the other hand, the political promotion game of local government officials allows them to focus on the political rank rather than the economic benefits brought by investment. The standard of selection and promotion of local government officials in China is an economic performance index, especially the local GDP growth rate. Therefore, government officials can possibly "waste" their capacity policies and regulations over inefficient projects for performance needs.

5.4.4. Quantitative relationship within the formation mechanism of coal production capacity

Out of backward production capacity and new capacity changes can promote changes in coal production capacity, and then integrate the coal production changes through the production chain. Every 1% increase in coal production capacity promotes coal production by 0.995%, and coal production, as an important part of the coal supply in the domestic market, inevitably generates changes in coal supply, thereby resulting in changes in the coal market supply and demand equilibrium. Coal overcapacity is the source of abnormal changes in the domestic coal market, thus resolving coal production overcapacity is urgent. However, the results in Tab 5show that coal supply and demand affect coal prices. Coal supply negatively influences coal prices, whereas coal demand positively influences coal prices, and the influence of coal demand on coal prices is more significant than that of coal supply on coal prices.

5.5. Model fitting effect test and robustness test

5.5.1. Model fitting effect test

From the above results, the R^2 of Eqs. (1)–(5), (7), and (8) are greater than 0.93 and the adjusted R^2 are greater than 0.91, indicating the good fit of the model to the samples. Explanatory variables can explain more than 91% of the variance explained. From the results in Table 5, the p-values of more than 90% of the parameters in the 10 equations of the model are all less than 0.05, demonstrating that the simultaneous equations fit the entire data.

5.5.2. Model robustness test

In this study, we remove the extreme observation points from the total sample and re-evaluate the above equation using the W2SLS method to further illustrate that the regression coefficient does not depend on a specific sample. From the results (Appendix A Table A1) we find that the regression coefficients of the equations are basically the same as those of the original samples by removing the extreme values of the variables. The main difference lies in the change of the coefficient size. Although the fitting degree of partial equation model is lower than that of the original sample, the influence direction and significance of the respective variables are basically the same as those in Table 5. Thus, the robustness of the regression equation of the simultaneous equations is confirmed.

Table 7
Output of the three control scenarios for 2015–2020 Billion tons.

Output result	Scenario settings	2015	2016	2017	2018	2019	2020
Elimination of backward production capacity	*MRS*	0.103	0.192	0.258	0.210	0.172	0.142
	CPE	0.109	0.218	0.294	0.258	0.228	0.202
	TPE	0.109	0.223	0.312	0.288	0.267	0.247
New capacity	*MRS*	0.298	0.121	0.122	0.130	0.142	0.157
	CPE	0.292	0.120	0.109	0.106	0.102	0.107
	TPE	0.295	0.120	0.115	0.116	0.118	0.119

6. Scenario control analysis of coal production capacity change

6.1. Scenario construction

China is a policy economy society, but market economy also exists that is committed to the development of market mechanism regulation. At present, China combines market mechanism and government regulation. Government regulation includes the level of the central government and local government affiliation and game relationship. Therefore, this article mainly explores the two types of exogenous variables under the market economy of construction-driven regulation and government direct regulation. The construction industry drives the development of four coal consumption industries and consequently drives the development of the coal industry, and government regulation can act directly or indirectly on coal demand, coal investment, and coal supply. In this study, we set three scenarios of the market regulation, market regulation and central government regulation, market regulation and control of the central and local government. The three situations represent the changes of exogenous variables to explore trends in coal industry demand, investment, capacity, production, and supply.

Many scholars at home and abroad construct different policy scenarios to analyze the relationship between energy structure and carbon emission, the effect of agricultural land use, and the supplementary and substituting effects between gasoline and ethanol. Feng and Zhang (2012) analyzed the developing trend of energy demand, energy structure, and carbon emission in Beijing from 2007 to 2030 in baseline scenarios (BAU), policy scenarios (BP), and low-carbon scenarios (LC) based on LEAP model. Feng and Li (2013) applied the Bayesian network model to analyze the use of the macro-regional policy and high-tech industry policy. Liu et al. (2015) used the Techno GIN model to analyze the use effect of agricultural land under the basic scenario, baseline scenario, and three different policy interventions, such as new nutrient management technology-related policies (e.g., soil testing and fertilization and fine nutrient management policies) and new agricultural management policies (e.g., moderate scale management policies).

Chen et al. (2013) constructed three case scenarios of a normal scenario, the 2008 “Sustainable Energy Policy Convention” scenario, and the 2011 “New Energy Policy” scenario based on the Taiwanese government’s energy policy and compared the three case scenarios’ energy mix for power generation for the next 15 years to further explore their possible impact on the electricity sector. Radu et al. (2016) presented 10 scenarios developed using the IMAGE 2.4 framework (Integrated Model to Assess the Global Environment) to explore how different assumptions on future climate and air pollution policies influence emissions of greenhouse gases and air pollutants. Debnath et al. (2017) created a structural economic multi-market multi-region partial equilibrium model considering the complementary and substituting effects between gasoline and ethanol demand considering the presence of policy driven domestic biofuel use (mandate) to explore the relationship between ethanol and gasoline. Menezes et al. (2017) built different policy scenarios to evaluate the potential of mitigating GHG emissions.

The formation mechanism of coal production capacity in China can be understood with the simultaneous equation model. According to the demand of domestic economic development and the national 13th Five-Year Plan, three different scenarios can be set, namely, market regulation scenario (MRS), central policy strengthening scenario (CPE), and two-level government policy strengthening scenario (TPE). The variation trend of production capacity and coal supply and demand situation in different scenarios in China from 2015 to 2020 is analyzed, and the results provide a quantitative reference for China to regulate production capacity.

6.1.1. Market regulation scenario

MRS is the dominant scenario, and active measures are not taken to resolve the coal production overcapacity. MRS is designed according to the present possible development pattern.

According to the status of resource consumption and energy demand, construction industry development is the main driving factor for strengthening the market in the allocation of resources. As the construction industry takes a decisive role, other measures are not implemented to cope with coal market overcapacity on the basis of 2014. Maintaining the development of this industry can cause coal supply and demand and capacity changes in the scenarios.

6.1.2. Central policy strengthening scenario

CPE is based on requirements of the national 13th five-year energy planning and domestic economic development planning. This scenario considers the current relevant policies and regulations as well as action plans and interventions of the central government to resolve overcapacity to achieve market and government collaboration. Changes in coal supply and demand with overcapacity will occur in CPE, under the conditions of ensuring the realization of economic and social development goals at the same time implementing and continuing the existing central to capacity policy measures.

6.1.3. Two-level government policy strengthening scenario

TPE fully considers the implementation of the central government policy by local governments. Under the joint efforts of the two levels of government policies, overcapacity can be largely resolved. The regulation of coal demand and supply becomes stringent and stable. The normative implementation of the policy measures and/or action plans is strengthened, and the production tasks can be completed.

6.2. Parameter setting

(1) *Level of Construction Industry Development.* Changes in the level of construction industry development majorly affect coal demand. However, with the adjustment of domestic economic structure and the continuous change of economic growth mode, the contribution of investment to economic growth will gradually weaken, and the demand growth of construction industry will slow down, thereby causing the construction industry to slow down. At present, the domestic economy steadily grows along with structural adjustment and people’s livelihood. Fixed asset investment will maintain a certain growth rate, but the growth rate will slow down. The growth rate of fixed assets investment in 2014, 2015, and 2016 are 15.75%, 10%, 8.3%, respectively. The future construction industry is in line with the growth rate of 5%–10%, according to the planning and construction requirements of the 13th Five-Year Plan, which expects the rate to remain at 7.64% from 2017 to 2020.
(2) *Central Government Control Policies*. Resolving overcapacity mainly

lies in the implementation of government policies. In this study, the prediction of eliminating backward production capacity is mainly based on the relevant energy policies and planning and design of domestic economic growth, including the "13th Five-Year Plan for energy development" and "the strategic plan of energy development (2014–2020)." In the context of production capacity, the central governmental policies promoting investment capacity will be significantly reduced, whereas the inhibition of production capacity investment policies and efforts to eliminate backward production capacity will be greatly enhanced. After 2016, "276" working days and other short-term production policies will gradually fade out, and policy strengthening will be reduced. According to the relevant policy objectives, policy intensity, and policy measures, the change of the intensity of the promotion capacity investment, restrain capacity investment, and backward production capacity can be forecasted (see Table 6).

(3) *Local Government Control Policies*. The existence of policy refinement degree and timeliness problem causes the central and local government policies in the process of implementation to exert different degrees of effect. In view of the local government policy mainly based on the central government policy, local government policy changes are smaller than central government policy changes. Table 6 provides the forecast situation of the intensity of the promotion capacity investment, restrain capacity investment, and backward production capacity under the three scenarios.

(4) *Coal Inventory*. Based on the requirements of the 13th Five-Year Plan, coal production and consumption will remain at 3.9 billion tons and 4.1 billion tons in 2020, respectively. The imbalance between supply and demand will be eliminated. The future coal inventory will be gradually reduced, with reference to the annual average growth rate of coal stocks in 2006–2012, that is −6.52%, and coal inventory is expected to remain at an average annual growth rate of approximately −7%.

(5) *Resource Endowments*. With the continuous mining of coal, which is a non-renewable energy sources, the future proved reserves of coal will be gradually reduced. According to the goals of 13th Five-Year Plan regarding the coal industry development and the average reduction rate in 2006–2014, the future of coal can reach reserves averaging an annual growth rate of −4%.

(6) *International Coal Prices*. The international coal price has certain influence on the net import of coal, but this study mainly considers the influence of the domestic market and the government policy on the production capacity and coal supply and demand. In the future, the international coal price market is in "moderate fluctuation." International coal prices are mixed, but the rate of change is very small, so the study sets international coal prices in the next four years as stable.

As can be seen from Table 7, the elimination of backward production capacity in TPE is 223 million tons in 2016, which has a small gap of 0.27million tons with actual backward production capacity elimination in 2016. The established model can predict the future development better. The elimination of backward production capacity exerts a slight effect in MRS but fails to meet the requirements of the national energy plan. The elimination of backward production capacity will bring significant effect after CPE is improved. Under the situation of enhancing the intensity of TPE, the elimination of backward production capacity will be 22.28% in 2020, indicating that the joint efforts of two levels of government will significantly promote the elimination of backward production capacity.

The results also show that the capacity investment in TPE has improved more than the situation under CPE in 2020, and the enhancement accounts for 11.21%, which is consistent with the findings of many domestic scholars (Zhou, 2007; Jiang et al., 2012; Wang et al., 2014). The one-sided pursuit of regional GDP of local governments and the promotion mechanism of local government officials specifically limit the local transition to pursue investment, resulting in increased investment in production capacity.

Coal production capacity in the three scenarios shows a downward trend by 2020 (Fig. 2). The decline in coal production capacity is the smallest in MRS mainly due to incomplete market reform of the coal market and weak market self-regulation. According to the forecast, the decrease of coal production capacity under CPE is obvious, indicating that the dominance of the domestic overcapacity is caused by the implementation of government policies. At the same time, coal production capacity will be further reduced in TPE. In the long term, the central and local governments need to increase the policy coordination capacity to quickly and effectively defuse overcapacity.

In this study, the external variables, such as construction industry development, are included in the scenario setting, and the coal production capacity and the change trend of the four coal-consuming industries are obtained. Changes of coal supply and demand in different scenarios are quantitatively obtained. Compared with the situation of coal supply under MRS, coal supply in CPE has been greatly reduced, which has decreased most in TPE. Han et al. (2016) thought that China's peak coal will reach 33–41*10^2 Mt from 2025 to 2030. Tao and Li (2007) used the STELLA model to analyze the factors of China's coal production and believed that China's coal peak will reach 3.339–4.552 billion tons from 2025 to 2032.

Taking 2020 as an example, coal supply under TPE is approximately 4.139 billion tons, which is down by 0.165 billion tons from MRS (Fig. 3). Coal supply maintains a great drop in the strict production capacity and reduced production policy measures and action plans. The obtained value shows a difference of 239 million tons with the 13th Five-Year Energy Plan requirement of 3.9 billion tons of coal supply. In addition to the coal mining mechanization degree of upgrading, coal information and intelligent construction substantially increase the production efficiency of coal enterprises. Reducing the mining activities of coal mining enterprises is only an expedient measure, if the market continues to follow production plans. The "data excitement" phenomenon in local areas exposes a number of coal enterprises dealing with rough handling or false documents to complete the task, resulting in overcapacity. Coal is consumable energy, and, thus, the change is less obvious. Scenario analysis shows that coal consumption in 2020 is roughly 4.03 billion tons, which is relatively close to the requirements of the 13th Five-Year Plan, in which coal consumption accounts for 58% of the total energy consumption, that is, 5 billion tons, equivalent to approximately 4.06 billion tons of raw coal. Compared with the coal supply in TPE, the imbalance between coal supply and demand is decreasing yearly. It shows that the two-way synergistic coordination between the market self-regulation and government policy regulation exerts a certain effect on the stable equilibrium and sustainable development of the coal market. The imbalance between market supply and demand still exists, but the difference is reduced.

The robustness of the model can be tested by removing the extreme sample, but there may be some errors in view of the insufficient sample size. At the same time, the data of this paper are mainly derived from the official data of China Statistical Yearbook, and the data of policy intensity are calculated according to the unified standard measurement. There are some errors in the determination of the standard scale and the determination of the assignment result. In this paper, the design of the scenario parameters is mainly based on the economic development of the past as the basis for the relevant coal-related industries issued by the government policy and development planning based on the domestic coal industry trends to predict, not yet consider the impact of the import and export policies and other factors.

7. Discussion and conclusion

7.1. Main conclusions

The following conclusions are drawn from the analysis.

a Currently, the construction industry leads the economic development of the coal industry in China. Construction industry development exerts obvious and continuous promotion effects on the development of the four major coal-consuming industries. At the same time, both construction industry development and coal price positively influence capacity investments. When the construction industry features a good development trend, the enterprises increase their investment in production capacity. Correspondingly, when the construction industry reduces the pace of development, companies reduce their investment.
b Coal production capacity investments are mainly affected by the construction industry development, coal prices, resource endowments, and government policies. Construction industry development, coal prices, and resource endowment as well as capacity investment exhibit the same trend; the three positive changes produce a positive impetus in capacity investments. The policies inhibiting and promoting investments promulgated by the central government exert a corresponding influence on capacity investments. The effect of the inhibiting policies is observed greater than that of the promoting policies.
c Elimination of backward production capacity and the effect of local government policy are generally better than that of the central government policy mainly because of the timeliness and low degree of the refinement of the central government policy and policy strength is weak. At the same time, the local government considers the needs of the protection of local economic growth, thereby recklessly pursuing investment, and not fully implementing the policy of reducing production capacity introduced by the central government.
d The slow elimination of backward production capacity, coupled with the accumulation of new capacity, allows the production capacity to remain at a high position without shifting down and gradually transforms into the increase in production and, together with the slow down domestic coal demand, leads to fluctuations in coal prices, affecting the changes in coal production capacity through capacity investment. Coal supply and demand influence coal price; coal supply negatively influence coal price, whereas coal demand positively influence coal price.
e Relying on the market's ability to adjust to resolve overcapacity only exerts slight effect. Relying on market regulation and strengthening the dual role of government policy regulation can reduce coal supply and the imbalance between coal supply and demand more quickly and steadily.

7.2. Policy recommendations

Based on the above analysis results, this study presents relevant policy recommendations.

7.2.1. Accelerate the reform of institutional mechanisms while improving and enhancing coal market system

Governments stimulate investment by stimulating economic growth, and then promote employment, coupled with the vicious competition between regions and overinvestments, inevitably leading to serious industry overcapacity. Therefore, the management of overcapacity should include reforming existing institutional mechanisms and adhering to market-oriented means to cope with overcapacity, thereby strengthening the market's function to correct the distortion of the existing system of the market so that the market can fully play its role. Specifically, the adjustment of the profit distribution mechanism between the central and local governments should be facilitated by reforming the existing performance index of local government officials, increasing the monitoring of local governments, and strictly supervising the effective implementation of policies.

7.2.2. Strengthen the level of government policy clarity and improve policy enforcement

The low degree of policy refinement of the central government has brought difficulties in the implementation of policies. The policy objectives are macroscopic, the policy measures are rough, and the ambiguity of policy exacerbates the evasive behavior of local governments. Therefore, the central government should refine the policy of production capacity and increase policy implementation and supervision as well as punishment efforts.

7.2.3. Promote the reform of the supply side of the coal industry and replace the construction-dependent growth model

The direct cause of overcapacity is supply and demand imbalance. The coal industry plays a great impact on the construction industry. The future reform of the coal industry must gradually remove the excessive reliance on the construction industry, actively promote the zombie enterprises to exit the market, encourage large enterprises to optimize mergers and reorganization, and further establish the exit mechanism of backward production capacity.

7.3. Discussion

First, this article only takes into account the effect of the construction industry on the coal industry. Other industries have yet to be considered. The study also does not consider energy-saving emission reduction constraints and industrial and energy structure adjustment on the coal industry development. Second, the local government policy in the study is only selected from 10 provinces. In addition, the comprehensiveness of the central and local policies cannot be ensured due to restrictions on access and methods. In-depth study from the aspects of energy-saving emission reduction constraints can be conducted in the future, along with the improvement of the policy quantification method.

Author contributions

All authors equally contributed to the writing of the paper.

Conflicts of interest

The authors declare no conflict of interest.

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Appendix A

Table A1
Estimates of simultaneous equations for removing the extreme values of the samples: robustness

Model	*LNFE*	*LNCS*	*LNCP*	*LNMP*	*LNICMW*
C		7.491292***	7.861152***	0.421088	8.818791***
		(0.263218)	(0.263218)	(0.794662)	(1.387565)
LNCS	−1.105381***				
	(8.02E-14)				
LNCS(-1)	0.444380***				
	(9.63E-14)				
LNCP	2.168618***				
	(8.22E-14)				
LNCP(-1)	−0.548553***				
	(1.07E-13)				
LNMP	0.040958*** (1.28E-14)				
LNMP(-1)	−0.240332***				
	(2.13E-14)				
LNIACI	−0.533615***	0.278139***	0.455511***	0.554468**	1.043454**
	(3.25E-14)	(0.078658)	(0.075849)	(0.237470)	(0.143648)
LNIACI(-1)	0.522416***	0.135908**	0.046905	0.344010**	
	(4.06E-14)	(0.064899)	(0.062582)	(0.237470)	
LNCCPI					0.112161***
					(0.077988)
CGPIAN					−0.037267***
					(0.007796)
CGPIAP					0.003584***
					(0.003394)
LGPIAN					0.087417***
					(0.006153)
LGPIAP					−0.034169***
					(0.007687)
LNRE					0.524994**
					(0.196344)
R-squared	1.000000	0.956105	0.969844	0.919828	0.997460
Adjusted R-squared		0.938547	0.957781	0.887760	0.979681

Model	*LNNC*	*LNEBPC*	*LNRP*	*LNNIC*	*LNCCPI*
C	7.673252***	0.834823***	9.870907***	−16.537052*	
	(1.165766)	(2.086869)	(0.603357)	(9.524563)	
LNBJ				−4.134813*	
				(2.644695)	
LNCCPI		−0.217521*		5.948523**	
		(0.431351)		(2.062419)	
LNCCPI(-1)					
LNICMW	0.208192*				
	(0.283479)				
LNICMW(-1)	0.126206*				
	(0.230071)				
CGPCA		0.001727**			
		(0.003115)			
CGPCA(-1)		0.000765			
		(0.002033)			
LGPCA		−0.002070**			
		(0.006606)			
LGPCA(-1)		0.002760*			
		(0.010747)			
LNCPC			0.796887***		
			(0.170826)		
LNS					−0.206034*
					(0.383205)
LNDE					0.598101**
					(0.381541)
R-squared	0.735945	0.894983	0.807426	0.890622	0.457549
Adjusted R-squared	0.610323	0.632441	0.765630	0.854163	0.380056

Note: The values in parentheses are the standard error of the estimates; ***, **, and * indicate significance levels of 1%, 5%, and 10%, respectively.

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