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A Predictive Analysis of China's Energy Security Based on Supply Chain Theory

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Abstract

China's energy dependence on energy supply chain have been increasing rapidly in recent years. The long-term energy supply plays an important role to guarantee the energy security. Therefore, our emphasis placed on energy supply chain predictive analysis and security evaluation in China. In this study, a linked MARKAL-CGE-EIA model system is proposed to simulate the macro-level energy technology, macro-level economy and environmental impacts of China. The CGE module is used to produce a multi-sector simulation of economic growth and industrial structure change. A MARKAL module is used to analyze particular technologies within the energy system, given estimates of associated energy demand and the relative prices of fuel and other inputs. A third module of Environmental Impact is applied to make an analysis of pollutant emissions. The energy indicators are used to perform an assessment of the dynamic behavior and security trends of a national energy system's trajectory from 2000 to 2050. The results of our study will enable energy policy planners to understand these inter-linkages by addressing energy early-warming indicators and scenarios to the aggregate industrial sectors, the energy technology details, and environmental impacts.

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Keywords: Energy security; Supply chain theory; CGE; MARKAL; China

1. Introduction

Over the past several decades, China has changed dramatically with respect to social tension, political power, and financial landscape. In recent years, the rapid economic development, expanding middle class population, motorization, and urbanization depend on energy resources and they have caused renewed concern about energy security and caused some rethinking about previous understandings [1,2]. This concern relates to finding the state and future trend of the national energy system that integrates the

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availability, accessibility and affordability [3,4]. Therefore, the crux of this discussion is "How do we simulate and measure national energy system and security level, and how do we interpret the measurements so that knowledge can best inform policy?"

Earlier literatures about supply chain management can go back to the Kraljic's paper in 1983, which emphasized the importance to take the risk arising from interconnected flows of material, information and funds in inter-organizational networks into account [5]. A unique factor that describes the supply chain system is the high degree of uncertainty. Hence, supply chain is inherent associated with risk [6]. The petroleum industry as a typical supply chain includes the exploration phase, crude procurement, storage logistics, transportation to the oil refineries, refinery operations, distribution and transportation of the final products [7]. Compared with other industries, the petroleum supply chain is extremely inflexible and complex, whose performance is also crucial for the national economy since it supports other activities. Clear understanding the risk in China's oil supply chain helps decision-maker to effectively manage the energy security from a systematic perspective. However, the application of supply chain to petroleum industry is still in its infancy [8].

The structure of oil supply chain must be depicted clearly before implementing the concept of supply chain to analyzing the China's energy security. According to the research of Carneiro et al [9], the oil supply chain can be divided into upstream and downstream segment: The upstream segment involves well prospecting, exploration, drilling and completion, and oil production. The downstream segment includes transportation, refining, and distribution of oil and refined products. Leung [10] suggests that current concept of energy security in China emphasized "reliable and adequate supply of oil" and paid less attention to the maintenance of "reasonable price". Wu et al. [11] applies improved portfolio theory to calculate the systematic and specific risks of China's crude oil import over the period 1994-2006. The result indicates that China can adjust import strategies to enhance oil supply security. Enyinda et al. [12] claim that the upstream petroleum supply chain contains exploration, appraisal, production and transportation of crude oil and gas to the refineries for conversion into finished products. Wu et al. [13] further explores the systematic and specific risk of crude oil and petroleum product imports based on portfolio theory and a diversification index approach. These literatures seem to be supply-based to clarify the concept of energy security.

The purpose of this paper is followings: (1) Clarifying the energy security combing with the background of China. (2) Identifying the main dimensions that affect the energy security according to the existed literatures from a new perspective. (3) Providing some corresponding policies to promote the energy security in China.

2. Methods

In this study, a linked MARKAL-CGE-EIA model system is proposed to simulate the macro-level energy technology, macro-level economy and environmental impacts of China. The linked model system is shown in Figure 1. The CGE module is used to produce a multi-sector simulation of economic growth and industrial structure change. A MARKAL module is used to analyze particular technologies within the energy system, given estimates of associated energy demand and the relative prices of fuel and other inputs. A third module of Environmental Impact is applied to make an analysis of pollutant emissions. Parameter changes to achieve consistency among the models are indicated by solid arrows in the figure. Energy early-warming indicators and scenarios are set with the connection between the aggregate industrial sectors of the CGE model, the technology detail of MARKAL and the environmental impacts of EIA model.

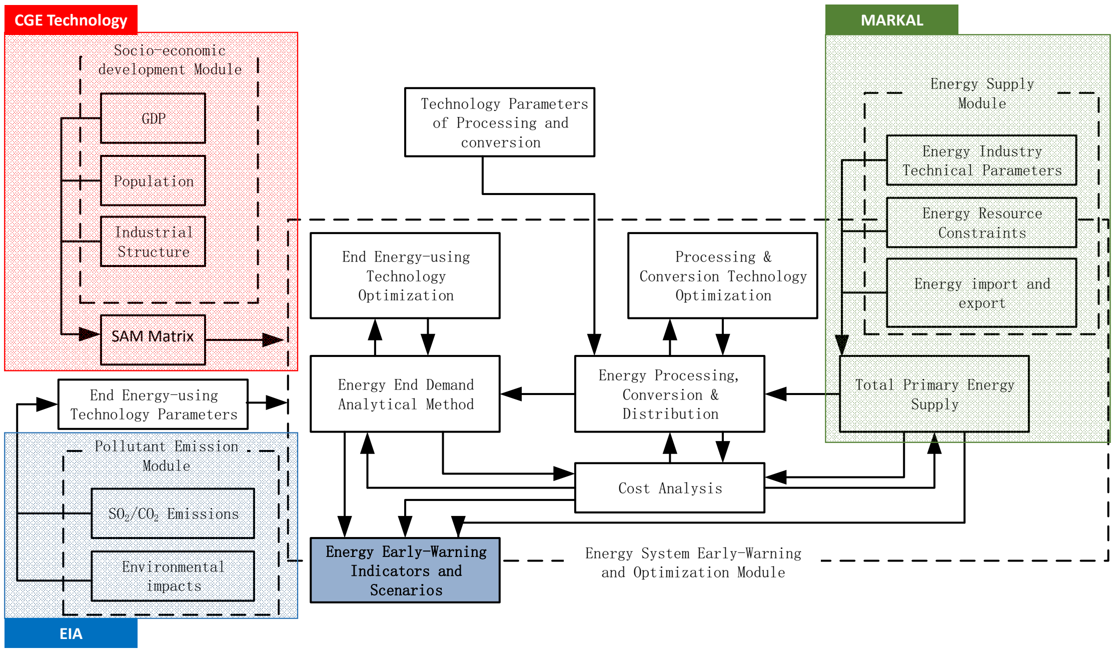

Fig. 1. The model of China's energy security analysis based on supply chain theory

3. Results

3.1. End-use energy demand analysis

(1) Sectoral composition of energy demand

The overall energy use in the industrial sector has been shown to ultimately decrease over time, while the commercial and transportation sectors will demonstrate an obvious increase. Similarly, the household sector (while not demonstrating as significant a change as the other sectors discussed here) also shows a steady increase. Finally, the agricultural sector demonstrates a decrease not only in terms of total volume of energy used but also in its percentage of energy use, and is forecasted to become the smallest sector with regards to energy demand in the future. Finally, with the energy consumption forecasted for both the commercial and household sectors dependant on the future development of construction sector, this study focuses on the end-use energy demands for both the commercial and household sectors while also examining their roles in the end-use energy demand of the construction industry. Similarly, we focus on energy use within the industrial, transportation, and construction sectors.

(2) Industrial sector

Within the four sectors discussed in the previous paragraph, the industrial sector's end-use energy demand will increase proportionally to the process of industrialization. This sector's energy use will maintain a slow and steady growth rate until the point at which industrialization has been nearly achieved. We estimate that the peak of industrialization will be reached in 2030, at which point it will level off and then and then slow down. As industrialization slows, the industrial sector's percentage in terms of total end-use energy consumption will also decrease, but is still estimated to account for about half of the total of all energy use by 2050. Additionally, urbanization tends to increase along with industrialization, notably so in the case of China's speedy urbanization linked to its special urban-rural dual structure.

Along with industrialization, China's urbanization will continue to boost the demand for high energy consumption products such as steel and cement in the industrial sector.

(3) Transportation sector

China's current transportation sector consumes 10% of the country's total energy use, an impressive number when compared to the 27.5% world average level and 34% OECD (Organization for Economic Cooperation and Development) country level. This is mainly due to China's current role in heavy industry associated with the intermediate stages of industrialization. With the industrial sector representing the primary source of energy consumption within China's economy, the transportation sector simply takes up a smaller proportion of energy (especially when compared to the already developed countries that have already achieved industrialization). With regards to the transportation sector, and increases in private car ownership forecasted for the future, we believe that transportation will develop efficiently and effectively without further draining energy resources.

All in all, with the optimization of and adjustments to the industrial sector expected in the future as industrialization progresses, end-use energy consumption will gradually shift from industry to the construction and transportation sectors. The percentage of fuel demanded for end-use energy consumption will continue to decrease to 1/3 of its current percentage by 2050; however, fuel is forecasted to remain the main source of end-use energy for the transportation sector. In both the construction and transportation sectors, with the transportation continuously relying more heavily on oil while construction turns to clean energy, the consumption of oil, electricity, and gas will increase greatly to 33% , 21.2%, and 11.9% , respectively, by 2050.

3.2. Non-fossil energy predictive analysis

To remain compliant with governmental policies, China will continue to promote the use of non-fossil energy. As such, by the year 2020 coal consumption presently delegated for the country's primary electricity supply will convert to 708 million tce (ton of standard coal equivalent). At the same time, China will effectively curb its growing energy demand to curb its primary energy consumption to less than 4.76 billion tons of coal in 2020, with non-fossil energy accounting for 14.8% of its primary energy consumption. Even with these reductions, China may not be able to reach its goal regarding non-fossil energy development. It should be noted, however, that this article calculates only the primary electricity contributed by non-fossil energy sources. If we were also to consider non-goods energy such as methane and solar energy, it is feasible that China's goal should be reached. Despite China's efforts to achieve both intermediate and long-term plans for renewable energy resources in 2020 (including the consumption of non-fossil energy to double when compared to 2010), total consumption is expected to increase rapidly, reaching 4.91 billion tce in 2020. Non-fossil energy resources are expected to account for less than 10% of this total.

According to the reference and policy scenarios illustrated above, China faces a significant challenge in achieving its non-fossil energy goals. In addition to vigorously promoting new and renewable energy sources, China must also curb the speedy growth of ESR if end-use energy demand and primary energy consumption are to be effectively controlled. Furthermore, when calculating its goal achieving rate, China needs to include the usage of non-commodity energy resources into its total for non-fossil energy consumption. Judging from the development trends we have witnessed, China still needs to make a large effort to fulfill its developmental goal of ultimately reverting to non-fossil energy sources.

On the other hand, with non-fossil energy mainly applied in the form of primary electricity, the international practice for calculating the contribution of non-fossil energy involves calculating its electro-thermal equivalent. In China, however, where the energy infrastructure is dominated by coal, primary electricity has always been calculated in accordance with coal consumption. In other words, the substitution of non-fossil energy for coal would be calculated as its energy contribution. According to calculations made by China's electricity department, the non-fossil energy contribution rate (when calculated using coal consumption for power supply) will be almost three times of that calculated by electro-thermal equivalent. This also lends to the non-fossil energy rate's sensitivity to coal consumption when determining power supply. Let's suppose that coal consumption for power supply in 2010 was 340 gce/kWh, and that this number decreases by 10 gce/kWh every ten years following 2010. In 2020, for example, non-fossil energy will be calculated at 330 gce/kWh. However, due to government policies such as Reform and Open up, China's rate of coal consumption for power supply has been decreasing at the speed of 4 gce/kWh. Recently, with the rapid reform of thermal power technology institutions (and with energy conservation and emission reductions both required in the "Eleventh Five-year-plan"), coal consumption for power supply has decreased dramatically. With this trend, and assuming that by 2020 the use of coal consumption for power supply will decrease by 30gce/kWh, China's primary electricity value will decrease by about 60 million ton of standard coal. In the end, this will reduce non-fossil energy percentage by 1 %.

It follows that China's goals for non-fossil energy development from 2020-2050 face difficulty and uncertainty; however, when considering sustainable development in terms of future energy use, it remains beneficial to speed up non-fossil energy development and optimize the primary energy infrastructure. Therefore, China urgently needs to develop a strategic plan to help it achieve these non-fossil energy goals.

Based on this analysis, and due to the close relationship between primary energy consumption and end-use energy demand, China's primary energy consumption will be determined to some degree by three future stages. We must define the characteristics of each stage in order to secure a strategic position for China's sustainable development of future energy.

- The first stage ranges from present day (2012) until 2020. This first stage is considered the key stage for controlling China's total volume of primary energy consumption. Due to the progression of industrialization and ultimate stabilization of the country's energy infrastructure and technology, this first stage will determine the trends and volume of future energy consumption. It is assumed that during this stage, the primary energy source for China will remain to be coal.
- The second stage spans the period between 2020 to 2050, the period we believe to be the most challenging in terms of the structural transformation of primary energy consumption. With industrialization reaching its peak and increasing energy demands within the construction and transportation sectors, coal consumption will steadily decrease while petroleum consumption is expected to remain vigorous. Gas and primary electricity consumption will also increase, especially when non-fossil energy enters a fast growth phase.
- The third stage spans the period from 2035 till 2050, and we anticipate this period to represent the stabilization stage for primary energy consumption in China. With the optimization of adjustments to the industry infrastructure, industry-related energy use will decrease steadily while construction and transportation-related energy demand will also slow. This means that primary energy consumption decreases while new energy demands are supported by alternate sources, such as low-carbon energy.

With these time periods forecasted for the use of primary energy consumption, China must develop a clear position for the future use of primary energy as soon as possible. This positioning will allow China to control its total volume and structure of primary energy consumption, thus meaning that available energy is able to support the economy while sustainable development meets environmental restrictions at the same time.

4. Conclusion

Through studying the characteristics of these time periods with regards to energy resources and consumption, China can plan ahead to the future. A plan is needed to determine how China's power consumption will be managed in the coming decades, especially in terms of developing non-fossil energy power generation. In turn, this plan will help to control the total volume, growing speed, and structure of thermal power. Additional benefits include support to the overall economy, the use of all available resources, advancements in technology and infrastructure in the area of energy supply, and contributions towards environmental protection and climate change.

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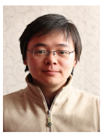
Biography



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