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유연탄 가격 예측 모형 개발에 관한 연구

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Contents

요약

석탄은 크게 유연탄과 무연탄으로 나눌 수 있다. 유연탄의 가격은 기본적으로 수요와 공급에 의해 영향을 받으며, 환율, 경제성장률과 같은 경제적 여건과 관련된 많은 요인들에 의해 좌우된다. 본 연구에서는 시스템 다이내믹스 방법을 이용하여 유연탄 가격을 예측하는 모델을 개발하였다. 이에 따라 변수들 간의 상호의존적 관계를 고려함으로서 실세계를 충분히 반영한 결과를 도출하였다. 본 연구에서는 유연탄의 가격을 결정하는 핵심 요인 8개를 분석하였으며, 대부분의 데이터는 2011년 5월부터 2013년 8월까지 2년 4개월간의 블룸버그 데이터베이스를 활용하였다. 인과지도는 회귀분석을 이용하였다.

표제어 : 유연탄, 예측 모델, 시스템 다이내믹스, 블룸버그, 인과 지도

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1. Introduction

Global coal reserves have been reported to be in an enormous level that can be used over the next 122 years at the current production level of 8,260 million tons a year. [1] After the late 1990s, the coal demand of energy consumption has been continuously increasing since the era of high oil prices. A recent trend of the international coal market shows that not only the market structure is changing from the long-term perspective but also the coal price volatility increases in the short-term period. [6] In particular, China, India and other emerging countries in Asia have increased coal imports dramatically from the late 2000s as the economy has been growing. [3] As a result, the market leader in the international market changed to the Asian market from the traditional European market. The share of Asia in the world coal imports increased significantly to 67% in 2010, compared to 51% in 2000. On the other hand, the share of Europe decreased by 12%, from 33% to 21% during the same period. [1]

International coal market has been greatly affected by natural disasters and the policies of major exporting countries. [2] For example, the coal supply condition has been exacerbated by Australia's coal production disruptions due to unexpected heavy rains. Furthermore, because of the surge in domestic coal demand, Indonesia and Vietnam restricted coal exports abroad, which resulted in the increase in the coal price. Coal exporting countries such as China, Indonesia, and Vietnam politically adjusted the amount of export to protect their own natural resources. [4] The Indonesian government restricted the export of coal less than 5,600kcal/kg from 2014 in order to induce domestic consumption and to raise the price of exports.

Global coal consumption is being made in the order of China, US, India, Japan. South Korea is the eighth largest consumer, accounting for about 2% of the world's coal. On the other hand, the global coal imports is being made in the order of Japan, China, Korea, Taiwan, and India. South Korea is the third importer, accounting for approximately 13% of the world's coal imports. The country's imports of coking coal accounts for 1.06 million tons in 2010. In detail, thermal coal was 82 million tons, accounted for more than 75% of the total coal imports and coking coal was 24 million tons, less than 25%. [5]

Coal can be divided into thermal coal and coking coal. Thermal coal is mostly used for power generation whereas coking coal is mainly used in the steel industry. Because thermal coal market size occupies more than 80% of the coal market and the two coals differ from market transaction, it is very reason to promote a separate study. Therefore, this study focuses on a methodology to estimate the purchase price of thermal coal only.

In this study, domestic power generation companies are to buy directly, the purchase price of thermal coal, which accounts for a high proportion of imported coking coal market to take advantage of modeled system dynamics method. To this end, this paper defines the factors that affect the international coal market and to take advantage of the system is to identify the model mix wife and their relationships to establish a model that can predict the international coal price.

In this study, we establish a simulation model based on a system dynamics method to estimate the market price of thermal coal. To this end, this paper first defined the critical factors affecting the international coal market price and established the relationship between variables. Finally, we verified the consistency of the model based on past record.

2. Theoretical background

There have been several previous researches applying system dynamics techniques to predict the price in various ways. Jeong et al. (2005) analyzed the effect of imposing a carbon tax on steel industry by using the System Dynamics. Gwak et al. (2002) also leveraged the system dynamics technique to develop monthly domestic car demand. In terms of raw materials, Jeong (2008) developed a system dynamics model of a nickel case, focusing on the supply and price forecasting. In addition, Jeong (2009) demonstrated a simulation model which explained freight transport price and iron ore. In this paper, we examined the articles which developed a system dynamics model focused mainly on raw materials.

2.1 Iron ore

Jeong (2009) explained the iron ore market determined by supply, demand and freight rates. Supply and demand had again non-linear relationship with the market price of iron ore. Through this, a simulation model has been developed to perform the analysis of the monthly local market prices of iron ore.

In this model, demand for iron ore is directly affected by steel production. China, Because of the fact that Thailand, Korea, Japan, and Europe are major steel production countries, the amount of monthly global iron ore import is determined by the monthly crude steel production in the same countries. The main iron ore producing countries are Australia, Brazil, and India. They are responsible for about 80% of world exports. Monthly supply of iron ore are determined by the sum of export of Australia, Brazil, India and other countries.

This paper applied marginal cost in order to determine whether a producing country want to export or not. If a domestic marginal mining cost is higher than the export price of iron ore, the amount of total production is assumed to decrease in proportion to the ratio falls short of the price. Finally, for the reason that iron ore transport fare occupies supply costs about 30 to 50 percent according to a route and region, the fare was included in the prediction model

2.2 Nickel

Jeong(2008) developed a system dynamics model that nickel price is determined by the demand over inventory ratio and the exchange rate. This paper constructed two sub-models which consists of demand part and supply part separately. Regions nickel demand is influenced by the price of nickel, local stainless production, and industrial production index. Nickel inventories is automatically generated by the demand and supply which affects the demand over inventory ratio in the system dynamics model.

Since the demand is typically divided into nickel for stainless production and for industrial usage, the two are reflected in the model separately. Nickel demand is mainly determined by major countries including United States, Europe, Japan, Korea, China, and Taiwan. The demand of other countries is estimated by multiplying a constant rate. Nickel supply is oligopolistic structure which a handful of companies and countries occupied. Quarterly nickel supply is modeled to include the deliberate production cuts by the sole supplier and reduction due to production disruptions.

In order to increase the statistical accuracy the forecast model calculated the most explanatory regression equation which describes the relations among regional nickel demand, stainless steel production, a demand over inventory ratio, and exchange rates.

As described above, in the case of iron ore and nickel model the researcher established a price prediction model focusing on the supply and demand of basic commodities. Furthermore, the model estimated the global demand and supply based on the sum of each major countries. In addition to considering the supply and demand factors, critical factors which has a critical impact on market structure are also included.

This paper not only reflected the results of previous researches considering basic market supply and demand but also reflected the uniqueness of the thermal coal market structure. Terminal core price, as the largest expense, is greatly related with power generation and the impact of other energy prices. [2] This paper strived to define key elements which affects a terminal core price significantly, and then figured out their impact and the importance.

3. Analysis

3.1 Methodology

A system dynamics technique, a dynamic model consisting of causal relationships based on a holistic approach, verifies the changes depending on various future environments and conditions through simulations. System dynamics provides results that better reflect the real world by employing an inter-dependent system of variables, rather than a system of unilateral interactions. It also enables the understanding of the interactions between factors as the focus is not limited to the causes of the changes in variables.

Unlike static models of linear reasoning, a system dynamics technique establishes a model based on holistic and long-term perspectives through holistic reasoning, which, by tracking the causality, extracts the feedback loop of causality that expresses the interaction between various variables and certain events. In order to better understand system dynamics, it is important to recognize the difference between a static and dynamic model.

A static model, comprised of unilateral, linear reasoning, is employed in various studies including the methods of regression equations or structural equations that explain the influence of A on B. Such static models use mathematical models or statistical methodology, and are static, partial, and short-term based.

However, a dynamic model analyzes parameters in bi-directional contexts and enables the expression of holistic reasoning due to its ability to confirm the feedback among variables. Most of the phenomena observed in the society are not uni-directional. There is a closed loop in which A influences on B, B on C, and C on A again. In order to reflect the real context, it is highly required to employ dynamic, holistic, and long-term perspectives.

A dynamic model identifies factors of influence and produces a causal loop diagram. It defines relevant factors on the basis of references, data, and its statistical analysis, and simulates the relations among the factors to explain the phenomena.

3.2 Criteria to select variables

The variables for the thermal coal price forecast model were chosen based on the importance of variables and their congruency with the data, where those variables of higher correlation with and bigger influence on the coal price are more important. In addition, the congruency of the data is one of the important criteria as the system dynamics analysis involves data collection and its analysis. This study is targeted to forecast the monthly change of the thermal coal price, for which the data should have monthly or more frequent records for the model.

Preliminary qualitative evaluation on the variables relevant to the price was carried out with the discussion with the experts at the power generation companies for purchasing coal, where twelve variables were selected among them. The analysis on the data to maintain their congruency excluded the world supply and the import on bituminous coal, the precipitation by regions, and the amount of alternative energy due to the difficulties in data acquisition, and selected eight variables for the system dynamics model.

3.3 Results of the variable selection

① The amount of imported thermal coal: The price of thermal coal is determined by the supply and demand. The majority of imported thermal coal in Korea was from Indonesia (46%) and Australia (31%) in 2010, and the import from China has increased recently. Therefore, the amounts of imported thermal coal from Indonesia, Australia, and China were selected for the thermal coal price forecast.

② The amount of exported thermal coal: Indonesia, the most exporting country of thermal coal in the world, is a major supplier of low rank coal. Australia, the most thermal coal exporting country until 2003, ranked the second in 2010, exporting 1.45 million ton that year, and is a major supplier of high-quality coal. In order to predict the thermal coal price, the amounts of exported thermal coal from major exporting countries were selected, which influences the supply of thermal coal.

③ Currency exchange rate: Currency exchange rate is not directly related with the thermal coal price. However, the transactions in the world market involve the US dollar, as a key currency, and local currencies, and the exchange rate against the US dollar is one of the variables that affects the export amount of thermal coal. For instance, a high exchange rate promotes more exports from the exporting countries.

④ Freight charge: The freight charge occupies a significant portion of the supply cost of coal. In general, the freight cost takes 10% of the coal price, but may increase as much as 30% at times. The same can be applied to the thermal coal price. Moreover, the irregular change of the freight cost mandates its adoption to the forecast.

⑤ Domestic coal price in China: As to the thermal coal market, China takes a very unique position. In the past, China was the biggest thermal coal supplier as well as a major coal exporting country. However, China is the second biggest importing country of coal, next to Japan, and imported 33 million ton in 2008 and increased the amount to around 100 million ton in 2010. The change has made the variation of the domestic thermal coal price in China directly affect the thermal coal price of Korea as well as of the world market. Therefore, this study employed the domestic thermal coal price of China as an independent variable of the model.

⑥ Electricity supply: The outlook of thermal coal demand in Korea is included in the Master plan for national energy of Korea, from which the demand for electricity generation can be calculated. The demands of thermal coal of other countries can be predicted from their electricity supply as most of the demand of thermal coal is for electricity generation.

⑦ Difference between the spot and future prices of alternative energy: The price of thermal coal tends to be synchronous with those of many primary products such as crude oil, copper, and zinc. In particular, the thermal coal price has shown very similar behavior with that of crude oil since 2005. Before 2005, the magnitude of the changes of the two prices was in significant difference although the directions of the two were the same. Since 2005, however, not only the direction of the two but also their magnitude has been in accordance since 2005. The synchronous movement is expected to be strengthened due to the increase of the international liquidity and the development of the spot market. This study reflects the price synchronization phenomena by including the crude oil price as well as that of copper and liquefied natural gas. Moreover, the difference between the spot and future prices of alternative energy is included as well in order to predict the variability of the thermal coal price in the future. The energy price is predicted not to increase when the spot price is relatively higher than the future price, and to increase when the future price is relatively higher.

Fig. 2 The price of thermal coal and crude oil

⑧ World economy: The world economy may directly influence the price of bituminous coal. Activated world economy increases the probability of a higher bituminous coal price. The stock indexes of the USA, Europe, Japan, China, and Korea were used in order to understand the variability of the world economy.

4. Employed model

The model in this study used the eight variables defined above in order to predict the price of thermal coal. The variables that directly affect the price are the amount of exported bituminous coal in the major exporting countries, the electricity supply, the difference between the spot and future prices of alternative energy, and the variability of the world economy. On the other hand, the price of thermal coal directly influences the amount of imported thermal coal in the major importing countries. The variables related with the amount of exported thermal coal in the major exporting countries are the currency exchange rates and the freight charge. In addition, the price of China's domestic thermal coal market is considered as an extra variable as the China market has both the exporting and domestic markets whose size is big enough.

4.1 Verification of the model

Most of the data of the variables were

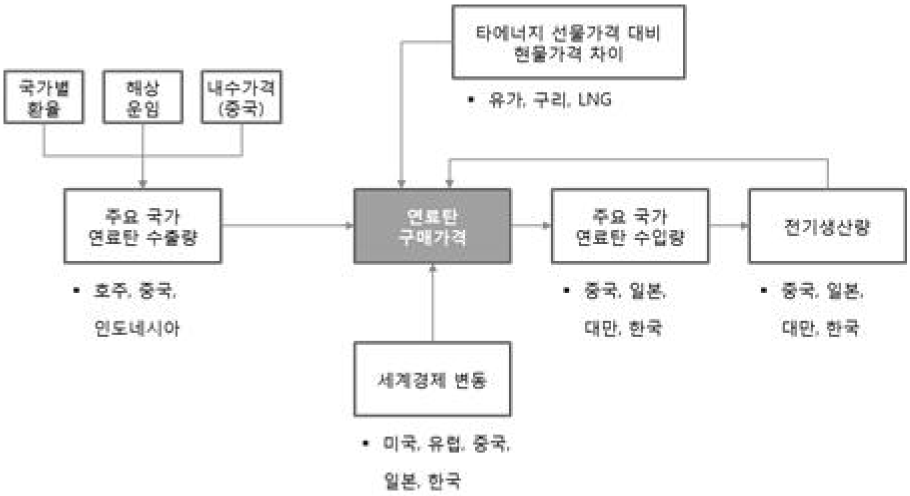

Fig. 3 Prediction model

Tab. 1 Regression equations for the thermal coal price prediction model

Dependent variables	Independent variables	Regression equations
GCI price	Export of bituminous coal, Electricity supply, Variation of alternative energy price, and Variation of the world economy	203.074+0.034*Global Ch-0.022*Export Major-0.022*Generation Major+0.523*Oil-0.636*copper-0.229*LNG
Export of China	Exchange rate of Chinese Yuan, Freight cost, Domestic demand of China, and GCI price	-14.424+1.133*Cumulative GCI Price-0.058*BCI2-0.091*Price Ch

Export of Australia	Exchange rate of Australia dollar, Freight cost 1, and GCI price	1586.29-7.036*Cumulative GCI Price+3.313*Currency Au+1.196*BCI1
Export of Indonesia	Exchange rate of Indonesian Rupiah, Freight cost 2, and GCI price	1407.23+4.646*Cumulative GCI Price +0.39*BCI3 +16.912*Currency In
Export of the major countries	Export of Indonesia, China, and Australia	Sum of the export amount of Indonesia, China, and Australia
Import of China	Supply of China	321+2.68e-005*(Import of China)-1.6e-012*(Import of China)ˆ2
Import of Japan	Supply of Japan	4.35e+007+8.94753*(Import of Japan)-5e-007*(Import of Japan)ˆ2
Import of Taiwan	Supply of Taiwan	3.25e+006+5.18747*(Import of Taiwan)-5e-003*(Import of Taiwan)ˆ2
Import of Korea	Supply of Korea	1.29e+008+3.13593*(Import of Korea)-2.3e-007*(Import of Korea)ˆ2
Electricity supply of the major 4 countries	Electricity supply of China, Japan, Taiwan, and Korea	(Electricity supply of Taiwan, Japan, China, and Korea) * (Change of World Stock Index)

acquired from the Bloomberg Database. The period extends to 2 years and 4 months, from May of 2011 to August of 2013. The imported amount of bituminous coal and electricity supply of Korea were acquired from the website of the Korea Energy Statistics Information System. Data sets recorded in a daily basis, such as the currency exchange rates, the stock indexes, the alternative energy price, and the freight charge, were converted into a monthly basis by a monthly average. The changes in the world economy and the alternative energy price were modified to their change ratios, where the change of the world economy was represented by the ratio over the past month and that of the alternative energy price by the change ratio of the spot price over the future price.

The causal relations among the variables were acquired by regression analysis.

The result predicted by the model from April of 2011 to November of 2013 is presented in Figure 4. The predicted price shows a similar behavior with the real thermal coal price movement during the period.

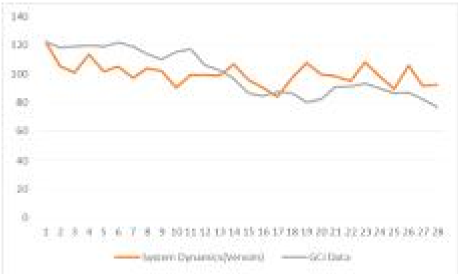

Fig. 4 Comparison of the model analysis results

4. Conclusion

In order to establish a model to predict the price of thermal coal, this study built a study model that forecasts the price by employing the system dynamics technique based on the previous studies that predicted the price of major raw materials such as iron ore and nickel. Variables that may affect the price of thermal coal were evaluated, from which eight variables were selected that directly influence the price and are in accessible data forms, based on the importance and data congruency of the variables. Finally, the system dynamics model was built while considering the causal relations among the variables and compared the predicted results with the real data collected in the duration of 2 years and 4 months.

The study used the system dynamics technique in order to make a prediction model of the thermal coal price from the causal relations among the variables. Various variables were evaluated and shortlisted to see their influence on the thermal coal price, which are then analyzed to see the causal relations.

The study did not focus on the world market of thermal coal in establishing the model and limited the scope to the domestic thermal coal price of Korea. The amount of imported thermal coal of Korea accounts for 13% of the world import, and the price is in close relation with those of other countries. Though the model did not reflect the influence of the price changes in other countries, it substituted the influence by calculating the amount of imported bituminous coal from the electricity supply of each country. This study targeted to predict a monthly change of the thermal coal price, but could not reflect the price change due to the variations in the market condition. It did not include the meteorological data which directly influences the supply and amount of export of thermal coal due to the difficulties in collecting accurate data on the precipitation. A more accurate model is expected when those limited variables are taken into account.

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Development of a Forecast Model for Thermal Coal Price

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ABSTRACT

Coal can be divided into thermal coal and coking coal. The price of thermal coal is basically affected by demand and supply. However, many other factors with regard to economic condition such as exchange rate, economy growth rate also make an influence on the price. This study is targeted to develop a forecast model for thermal coal price by using System Dynamics Method. System dynamics provides results that better reflect the real world by employing an inter-dependent system of variables. This study found out that 8 factors have important influence on the thermal coal price. Most of the data of the variables were acquired from the Bloomberg Database. The period extends to 2 years and 4 months, from May of 2011 to August of 2013. The causal relations among the variables were acquired by regression analysis

Keywords: thermal coal, forecast model, system dynamics, Bloomberg, causal loop

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