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Original Article

Statistical model for forecasting uranium prices to estimate the nuclear fuel cycle cost

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ABSTRACT

This paper presents a method for forecasting future uranium prices that is used as input data to calculate the uranium cost, which is a rational key cost driver of the nuclear fuel cycle cost. In other words, the statistical autoregressive integrated moving average (ARIMA) model and existing engineering cost estimation method, the so-called escalation rate model, were subjected to a comparative analysis. When the uranium price was forecasted in 2015, the margin of error of the ARIMA model forecasting was calculated and found to be 5.4%, whereas the escalation rate model was found to have a margin of error of 7.32%. Thus, it was verified that the ARIMA model is more suitable than the escalation rate model at decreasing uncertainty in nuclear fuel cycle cost calculation.

1. Introduction

In the case of nuclear fuel cycle cost, the uranium cost takes up a significant portion of approximately 26–30% [1]. Accordingly, it is necessary to forecast the future uranium price even more accurately in order to decrease the uncertainty of the nuclear fuel cycle cost.

Uranium recorded its highest price in 2007 at approximately 140 US$/poundU (Uranium). Since then, the price has decreased and is now at approximately 40 US$/poundU (March 2015). The reason why the price of uranium soared in 2007 is that there was an imbalance between uranium demand and supply. Uranium prices can change owing to various external factors, in addition to the above mentioned imbalance of demand and supply. For example, since the Fukushima nuclear accident that took place in Japan, the share of nuclear power generation as part of total electricity generation of nuclear power generating nations in the European Union (EU), including Germany, has decreased. As such, the demand for uranium decreased until May 2014. Moreover, uranium demand may decrease, because nuclear power generation has decreased owing to shale gas development and decreases in oil prices [2]. However, shale gas distribution is currently vast, and significant cost is expected to be incurred in developing the infrastructure required for gas development [3,4]. Thus, shale has yet to significantly affect the share of nuclear power generation. Moreover, it is expected that uranium prices will not decrease in the long-term because oil price decreases are limited over time as well.

Germany, the representative nation in the EU in terms of decreased nuclear power generation, has increased its share of electricity generated from new and renewable sources. As such, its generation costs have increased significantly. Accordingly, electricity consumers in Germany are experiencing significant difficulty owing to the increase in electricity prices. In the end, advanced EU nations that are lowering their share of nuclear power generation have yet to find an alternative energy source that can effectively replace nuclear power generation. For example, neither solar heat nor wind power can produce a sufficient amount of electricity to replace nuclear power. Moreover, new and renewable energy sources cannot produce electricity stably during weather changes. Thus, they are considered unfit as a power supply base.

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One of the key reasons why uranium prices have increased is that rising nations such as China are continuing to construct many nuclear power plants in order to cope actively with climate change, and to sufficiently supply the electricity needed for their economic advancement. China plans to construct approximately 100 nuclear power plants on its eastern coast. Accordingly, the construction of China's nuclear power field is expected to significantly affect future uranium prices around the world, and will increase uranium prices.

If it is possible to forecast uranium prices relatively accurately, it will be possible to identify the right time for purchasing needed uranium at a low price, and to secure a necessary uranium inventory. Moreover, this study will contribute significantly to an assessment of the economics of the nuclear fuel cycle because it will be possible to increase the accuracy of uranium cost prediction, which is a key cost driver for nuclear fuel cycle costs [5,6]. Accordingly, this paper utilizes a time-series analysis method, which is a statistical method that uses past data to forecast future uranium prices. In other words, future uranium prices are forecasted by utilizing the autoregressive integrated moving average (ARIMA) model according to the procedure shown in Fig. 1.

2. Uranium price forecasting model

A nuclear fuel cycle economic analysis that uses a dynamic model involves an engineering cost calculation method. In other words, the uranium price at each year in the future is calculated by factoring in the escalation rate with the uranium price of the base point. This uranium price is used as the input data for the nuclear fuel cycle cost calculation. Accordingly, the nuclear fuel cycle cost's uncertainty decreases when the future uranium price is accurate [7]. However, a significant price trend difference was found between the actual uranium price and uranium price values that were forecasted using the escalation rate model, as shown in Fig. 2. Accordingly, the value for calculating the sum of the uranium cost for each year according to the current value is bound to yield a significant difference.

Thus, in order to decrease the nuclear fuel cycle cost, calculation of the uranium price per year in the future needs to use a scientific estimation method that can come up with a figure that is close to the actual price, without uncertainty, because the uranium cost is a key cost driver of the nuclear fuel cycle cost [8]. For this reason, after identifying the various time series analysis models that can rationally forecast the uranium price for each year in the future with very high uncertainty, this paper presents the most suitable model. First, an escalation rate model and the theoretical concept of the statistical model, which are being used in the existing engineering cost estimation method, were examined.

2.1. *Consumer price escalation rate model: Uranium price forecasting model that factors in the consumer price escalation rate*

In the case of the nuclear fuel cycle cost calculation field, which has used a dynamic model until now, the uranium price for a certain standard year was set as shown in Eq. (1) [9], and only the consumer price escalation rate was factored into this value to forecast the future uranium price. These data are used as the input data for the nuclear fuel cycle cost calculation. Because this research paper considers only the consumer price escalation rate, the model was called the "escalation rate model." When the standard year's uranium price is calculated according to the uranium price of the previous year using the consumer price escalation rate model, the uranium price increases in a linear manner [10]. When the uranium price for a year is calculated according to the standard year's uranium price, the uranium price increases as time moves forward. Accordingly, because the uranium price that is forecast with the consumer price escalation rate model continues to increase, a disadvantage is that a significant difference from the actual future uranium price may result. However, the escalation rate model is often used today because of its advantage that the rough future uranium price can be estimated promptly [11].

$$UP_t = UP_b(1+e)^{(t-b)} \quad (1)$$

where UP_t = uranium price at year t, UP_b = uranium price at base year, e = escalation rate, and b = base year.

2.2. *Time-series analysis model*

The ARIMA model is one of the time-series analysis models; it is used as a statistical forecasting method, and is also referred to as the Box-Jenkins model [12–15]. By performing model identification, discerned model parameter estimation, and testing statistical

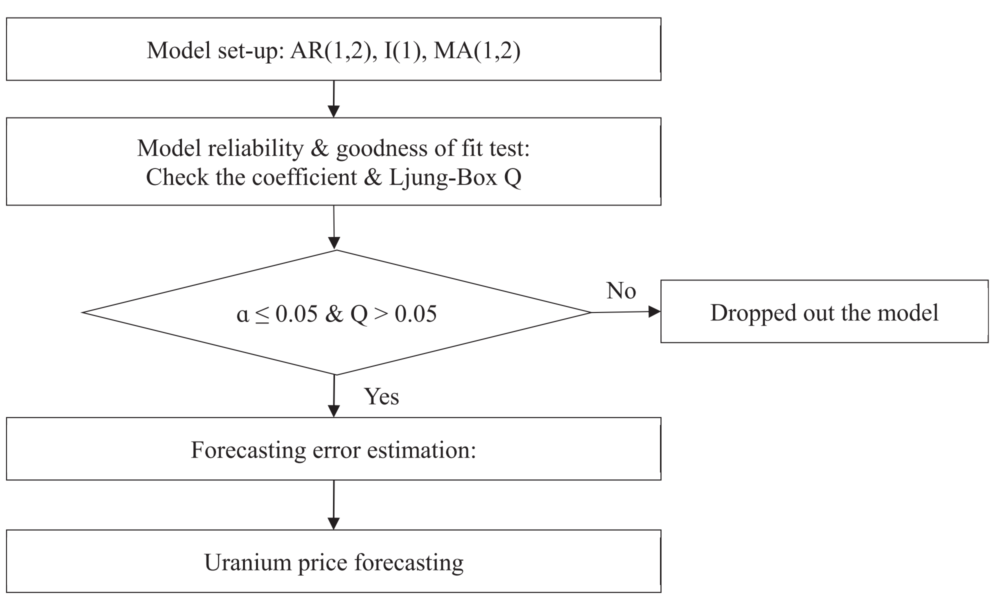

Fig. 1. The procedure of forecasting uranium price using the autoregressive integrated moving average (ARIMA) model.