The Safety Stock of Coal during the "12th Five Year"

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Abstract

During the period of "Twelfth Five-Year Plan", China's energy structure is dominated by coal. Due to a few reasons in our country, such as uneven distribution of coal resources, the bottlenecks of railway transportation, the problems of coal resources integration as well as the bad weather and other factors, China's coal supply presents the characteristics of fluctuation and uncertainty which make it difficult to meet the demand for coal. To ensure the stable supply of national energy, there is need to determine a reasonable coal inventory level. This has a vital significance with regard to China's security of energy supply during the period of "Twelfth Five-Year Plan". Based on the previous research on safety stock, the article establishes a new model of safety coal inventory, aiming at coal production, coal demand uncertainty, the customer service level and other specific circumstances. The article offers a new train of thought for early warning in coal industry and has provided the basis for forecasting coal safety inventory during the period of "Twelfth Five-Year Plan". In 2011, the actual data basically coincide with the predicted model data, establishing a preliminary evidence that the model is basically reasonable and effective.

Keywords: The Coal Industry, Coal Safety Stock; Energy Security

1. Introduction

Energy is the lifeblood of the national economy and energy security is an important guarantee of sustainable economic development. According to China's energy consumption structure, coal has a special significance for China. In the current stage of world energy consumption, the three major energy, crude oil, natural gas and coal, each takes up about 30%. But as for China, coal provides about 70% of energy and more than 60% of chemical raw materials. China is one of the few countries which takes the coal as the main energy, because China is relatively scarce of oil, gas, and water resources[1]. In recent years, China's energy structure is undergoing major adjustments and some progress has been made, but the dominant position of coal in the energy mix will not fundamentally change. In the next few decades, coal will continue to be a realistic and irreplaceable energy basis for China. Therefore, the coal has a special significance for China. China's coal reserves are relatively abundant, and its advantage of price is obvious, and that will make the coal continue as the primary source of energy supply in the coming period. The coal will still be a big part of China's future energy consumption. Recently, the development of coal industry is a little too fast, and so many problems have appeared, i.e. capacity expansion is too rapid, foundation of production safety is weak, industrial structure is fragmented, etc. which may result in a big risk of imbalance between coal supply and demand, and the entire national economy and coal industry may be adversely affected. Because of numerous mine disasters, strengthening the safety rectification of small coal mines and integrating and restructuring small coal mines will become an important factor affecting the coal supply, plus transportation structural contradictions, bad weather and unpredictable factors, coal enterprises need safety stock of coal to meet customer needs. To ensure the safety of national energy supply and the stable development of national economy, to push the coal industry into a track of healthy and sustainable development, and to maintain the overall stable balance of the coal supply and demand, coal stocks, as a regulator of the coal market supply and demand, must be maintained at some reasonable level. And efficient inventory management is a complex process which entails the
management of the inventory in the whole supply chain. The dynamic nature of the excess stock level and shortage level from one period to another is a serious issue[2]. Basing on a research on coal stocks, this article proposed a reasonable level of coal safety stock.

2. A review

2.1 Inventory management and safety stock

Inventory management is the key to achieving cooperation among supply chain nodes and achieving the supply chain integrated management. Inventory management technology has been an important research area of supply chain management technologies. In the rapid changing market competition environment, supply chain contains a lot of uncertainties. These uncertainties are mainly in two forms: Uncertainty of interface and uncertainty of operation. The uncertainty of the supply chain has had a significant impact on supply chain inventory. Companies need a certain stock to meet customer demand in time and to avoid being out of stock or face the uncertainty of the supply chain. The purpose of inventory management is to control the inventory levels of the enterprise, to reduce inventory levels as much as possible, to reduce the cost burden of enterprises and to improve the market competitiveness of enterprises under the premise of maintaining a high level of customer service [3].

Safety stock is setting a certain number of inventories in order to cope with the demand, the production cycle or supply cycle possible changes. It is for the compensation when actual demand outnumbers expectation demand or actual orders outnumber the expectations of the order cycle during supplementary supply lead time. If there is no safety stock, and demand outnumbers expectation during lead time, there will be shortages.

2.2 The necessity of setting safety stock of coal

The uncertainty of coal supply and demand, shortage cost factors determine the complexity of coal inventory and the necessity of safety stock settings.

(1) The uncertainty of the coal production

The specificity of coal production determines that coal production has the characteristics such as continuity, the importance of safety, and accident occurs suddenly. The reasons can be as follows: ① Coal enterprises has a long preparation period for production, the complexity of production process leads to the result that the production plan doesn't reflect the actual production conditions precisely or forecast the changes of the production environment, and causes deviation between the plan and the actual. ② Coal enterprises are mostly underground operations. Accidents often take place and cause the instability of production. ③ Coal supply is restricted by the conditions of transport. The long distance of coal transportation, bad weather and other factors lead to delays. Meanwhile, coal transportation capacity, transportation conditions and other factors, as the bottlenecks of the use of coal, are important factors affecting the optimizing of the decision-making process of the coal supply chain. ④ Coal is restricted by coal mining conditions (such as gas, security, seam thickness, etc.), and the quality of coal is also subject to the ash content of the coal seam, volatile matter, sulfur content, etc. It is difficult to obtain stable coal quality and production.

(2) The uncertainty of demand for coal

The demand for coal is uncertain mainly because: ① Demand forecast has deviation, any prediction method has some defects, thus cannot predict exactly the fluctuations in demand and corporate psychological reaction in decision-making process. ② Demand fluctuates with season changes. ③ Shortage cost

Shortage cost is the cost produced by external or internal interrupt of supply. The scale of shortage cost depends on the reaction of customers to the situation when out of stock. The shortage cost includes business loss and the decline of corporate reputation, reduced profits and other loss caused by the inability to meet the needs of customers; the loss of sales opportunities; Downtime to be expected losses and extra expenditure from delayed delivery. Coal is related to the national economy and people’s livelihood. It is not just the matter of coal enterprises' profit and credibility. Once coal is of shortage, it would affect the normal production and life of the whole country. Thus not setting up coal
safety stock is undoubtedly equivalent to hanging a sword on the economy lifeline [4].

2.3 Review of relevant theories

Safety stocks are commonly used in inventory management for tactically planning against uncertainty in demand and/or supply. So far, most of the studies on coal stocks adopted the perspective of supply chain management, in which inventory management is the core. Inventory theory can be traced back to the late 19th century when the banks needed to determine and maintain a reasonable level of cash flow. In 1915, Harris took a detailed study on bank currency reserves, established a deterministic model on inventory cost, and gave out the optimal solution, which is called “the best batch formula”. This model is subsequently developed into a deterministic inventory model and is the originator of the stochastic inventory model. As an independent and known theory, inventory theory was born in the 1950s. In 1953, Whitin wrote the book The Theory of Inventory Management, followed by Studies in Mathematical Theory of Inventory and Production, a book by Arrow in 1958, which refined the mathematical theory for the problems production and inventory. In 1959, Moran wrote the book Storage Theory. Since then, inventory theory became an independent branch of the Operations Research. Basing on inventory theory, scholars both domestic and abroad had proposed the safety inventory theory on coal stocks.

Earlier studies on safety stock are mainly based on the economic order quantity or based on statistical knowledge, safety stock, mainly to solve the problem of the cost in mass production. Modeling of inventory in the supply chain environment includes multiple types of inventory modeling: Inventory modeling in complex product demand mode, inventory modeling complex under objective function, multi-cycle environment inventory modeling and multi-product environment inventory modeling. In early years, research on the safety stock formed four main branches: Collier, D.A and others studied the influence of common software on safety stock. They mainly studied the relationship of general parts strategy, lead-time and inventory: general parts strategy is advantageous to shorten the lead-time, and this is advantageous to reduce the inventory; Peter studied the impact of supply uncertainty, the aggregation effect to corporate safety stock; Baganha and others discussed how to manage safety stock in multi-level inventory systems; one of the main branch is the application of artificial neural network, which uses BP neural network model in data simulation, in order to forecast the safety stock.

In recent years, the research in this area has some new progress. Kanet, Gorman and Stosslein introduce a new line of research in inventory management: the notion of planning time-phased safety stocks[5]. Because the uncertainties in demand and/or supply are studied in isolated instances. The current literature largely neglects case study based contexts and, often, single product situations are investigated in which machine set-ups are not considered. Van Kampen, Tim J, and his working partners investigate the effects of safety stock and safety lead time on delivery performance in a multi-product setting[6]. Funaki, Kenichi presented a strategic safety stock placement model in supply chain design for assembly-type product with due-date based demand, where demand data are based on dates when company has to ship to customers rather than order receiving dates[7]. etc.

Domestic energy security research focused largely on building energy security early warning indicators system[8]. Attention was given to the supply uncertainty in recent years. Many domestic experts and scholars also engaged in related research, Xu Yingchun, Ruan Wenbiao studied the impact of uncertainty in supply chain to safety stock[9]. Jia Hongyu and Hu Songyun discussed the control method to safety stock based on the multi-agent. Tian Hao, Liu Caihua tackled the manufacturer's safety stock model in a JIT environment[10]. Mu Qingguo, from the perspective of raw coal production enterprise, established a basic model of multi-cycle inventory for economic raw coal output and the amount of guaranteed reserves[11].

In addition, many domestic researchers studied the safety inventory model for supply chain security in the circumstances of demand uncertainty and lead time uncertainty, which enriched the methods of supply chain control both in theory and in practice.

Basing on the basic results of previous studies and combining with the actual situation of the Chinese coal market, this paper is to propose a coal safety stock model, and to use this model in the forecast and early alarming of the coal industry.
3. Coal safety stock model

Energy is the lifeblood of national economy. Energy security is an important guarantee of sustainable economic development. Looking from the perspective of China's energy consumption structure, China is a country relatively poor in oil, gas and other resources and is only relatively abundant in coal resources, which also determines that the energy structure in China is dominated by coal and coal accounts for about 70% of total energy consumption. In recent years, China's energy structure is undergoing major adjustments and some progress has been made, but the dominant position of coal in the energy mix will not fundamentally change. According to the International Energy Agency forecasts, till 2030 coal will still account for 60 percent of China's total energy consumption. But China's coal supply is affected by many factors, such as the uneven distribution of coal resources in China, the constraints of railway transportation bottleneck, the integration of coal resources, as well as the inclement weather and other factors. Therefore, coal-related businesses need to save a certain amount of coal stocks to respond to possible changes.

Unexpected changes may occur in demand, the production cycle or supply cycle. Thus coal safety stock is needed in order to compensate for the additional coal supply when real demand is in excess of expected demand during the lead time or when real lead time of order is in advance of expected lead time of order.

Coal stocks are constrained by money fund, coal prices, conditions of transport, reception conditions, storage capacity of coal warehouses, unloading capacity, etc. With the technical coefficients and resource constraints, planning models can be easily created, and the optimal solution can be calculated with data input. The above constraints are often assumed to be stable, whereas, the truth is that coal supply and demand are affected by factors of policy change, natural conditions, as well as the coal market supply and demand situation, the tension in the coal market, sensitivity in coal transport system, etc. So there are many uncertainties. It is the volatility and uncertainty that constitute the fundamental difficulty in the control of coal safety stock which require the scientific and reasonable setting to the safety stock.

3.1. The determination of the amount of safety stock

According to the theory of safety stock, the value of safety stock depends on three factors: 1) the level of customer expect to inventory service; 2) the degree of uncertainty in supply to enterprises; 3) the degree of uncertainty in demand faced with enterprises.

From the perspective of the level of customer expect to inventory service, the service level of inventory represents the ability of stocks in meeting with user needs. If the user is always able to get the items at the time of need, the service level is 100%, or else it is less than 100%. Level of service and level of short supply is 100%. Different levels of service have different safety factor, the safety factor reflects the enterprises' capabilities of customer service.

From the perspective of the relationship between lead time and safety stock, lead time refers to the elapsed time from the time point of ordering to the time point of delivered, which can be represented by L. Clearly, no matter the demand changes or not, with the increase of L and its fluctuations, the amount of safety stock will be greater. The delivery lead time will follow a normal distribution. Therefore, we can use two indicators to measure:

\[ L: \text{the average length of the lead-time} \]
\[ \sigma_L: \text{the standard deviation of the lead-time to measure degree of deviation of the lead-time} \]

From the perspective of the relationship between uncertainty of demand and the safety stock, with the increase of the degree of demand uncertainty, safety stock will increase.

From the above, among the factors of uncertainty that affect the safety stock, the most common are the changes in demand and lead time and the level of service to user demand.

If the lead time is not changed, then it is specified by the terms of the contract. For example, the procurement of coal is carried out at coal ordering fares, where the customer signs contracts with coal companies to determine the amount of demand for coal, and the estimated time. If the historical distribution of demand is known, then the safety stock should be determined basing on the principle of minimum safety stock costs.
\[ Ss = Z \sigma_D \sqrt{L} \]

In the above:  
- \( Ss \) - safety stock;  
- \( \sigma_D \) - standard deviation of demand - during the lead time;  
- \( L \) - the length of the lead time;  
- \( Z \) - factor of the service level (the level of customer service are translated into standard deviation).

If customer demand in the lead time is identified, but the lead time is variable, then in this case:
\[ Ss = Zd \sigma_L \]

Where:  
- \( d \) - daily demand in the lead time;  
- \( \sigma_L \) - the standard deviation of the lead time;.

If the lead time and demand changes randomly, then assume that customer demand and lead time are mutually independent, then
\[ Ss = Z\sqrt{\sigma^2_D + \bar{d}^2 \sigma^2_L} \]

Where:  
- \( \bar{d} \) --- the average daily demand during the lead time  
- \( \bar{L} \) --- Average length of the lead-time

3.2. The determination of coal safety stock

The above is a general analysis to safety stock from the perspective of an enterprise, and the formulas of safety stock are built respectively on conditions of changing and unchanging lead time. Through the above analysis, combined with the actual situation of coal from the coal supply chain perspective, the level of coal safety stock depends on three factors: 1) expected inventory levels by coal users; 2) the degree of uncertainty of the coal supply; 3) the degree of uncertainty of coal demand. In the "12th Five-Year" period, China will need consumption control on coal. Hence, here we introduce the adjustment factor for the adjustment of coal demand. According to China's coal procurement, the lead time for coal safety stock is relatively constant, and the coal supply capacity can be seen as the factor of the level of service, then adding the adjustment factor, coal safety stock can be calculated as:
\[ Ss = Za \sigma_D \sqrt{L} \]

Where:  
- \( Ss \) - coal safety stocks;  
- \( \sigma_D \) - standard deviation of coal demand  
- \( L \) – the level of coal storage in the number of days  
- \( a \) - adjustment coefficient  
- \( Z \) – the capacity of secured coal supply

4. China's coal safety stock levels during "the 12th Five-Year" period

In the above, coal safety stock model is given out. According to the model, the calculation to coal safety stock needs to determine the demand, the adjustment coefficient, the capacity of secured supply and the normal days of coal storage.
Where, the coal demand is the coal consumption by electric power industry, steel industry, building materials industry, chemical industry. Data of coal consumption are from bodies in China's coal industry. By the model analysis, capacity of secured supply complies with the normal distribution. According to normal distribution table, the capacity of secured supply can be conversed into the standard deviation (coefficient of secured supply), which is shown in Table 1.

<table>
<thead>
<tr>
<th>capacity of secured supply (%)</th>
<th>84.13</th>
<th>90.32</th>
<th>94.52</th>
<th>96.41</th>
<th>97.72</th>
<th>98.93</th>
<th>99.53</th>
<th>99.87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Z (coefficient of secured supply)</td>
<td>1</td>
<td>1.3</td>
<td>1.6</td>
<td>1.8</td>
<td>2</td>
<td>2.3</td>
<td>2.6</td>
<td>3</td>
</tr>
</tbody>
</table>

Considering the importance of coal in the healthy and sustainable development of the national economy, service level of coal should be close to 100%, but still considering the uncertainty in coal production and demand, combined with China's actual situation, to secure various aspects of the coal supply, we have chosen the capacity of secured supply as 94.52% and the corresponding coefficient is 1.6.

The number of Normal days of coal storage should be determined according to the real situation of power plants, coal mines, steel mills and other settings. Presently, coal inventory in all aspects is apparently significantly low. In the next few years, with the gradual establishment of national emergency coal reserves and the local utility coal reserves, coal storage both in transit and consumption places will show a rising trend, days of coal storage in all sectors will also be raising. Specifically seeing, for the power plant, days of coal storage is about 15 days, but in the abroad such as the U.S., coal storage days for power plant is more than 50, even a month's Blizzard will not affect power generation, in Japan, the European Union and other regions, coal storage is usually above one month. Considering the situation of power plants in China, in 2015, the days of coal storage in power plants should be about 45 days. Steel plant is also the end user of coal, coal storage by the number of days should be increased to a certain level, according to the steel coal circumstances, it should be about 40 days. Coal mines, as the main suppliers of the coal storage, the number of days of coal storage is allowed not to be too high, but by 2015 it should be increased from the current six days to about 10 days. Port has a very important role in the security of coal supply, coal storage in the number of days for ports should be raised to about 25 days. During the "12th Five-Year" period, China will begin coal consumption control. With the comprehensive consideration to the various aspects, normal coefficients for coal storage and accommodation are as follows:

<table>
<thead>
<tr>
<th>Society as a whole (Max, Min)</th>
<th>Key coal mines (Max, Min)</th>
<th>Major ports (Max, Min)</th>
<th>Focus power plant (Max, Min)</th>
<th>Core steel Plant (Max, Min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Adjustment coefficient</td>
<td>1</td>
<td>0.4</td>
<td>0.8</td>
<td>0.7</td>
</tr>
<tr>
<td>Year 2011</td>
<td>28, 30</td>
<td>6, 7</td>
<td>16, 18</td>
<td>18, 22</td>
</tr>
<tr>
<td>Year 2012</td>
<td>31, 33</td>
<td>7, 8</td>
<td>19, 21</td>
<td>23, 27</td>
</tr>
<tr>
<td>Year 2013</td>
<td>34, 37</td>
<td>8, 9</td>
<td>22, 24</td>
<td>28, 32</td>
</tr>
<tr>
<td>Year 2014</td>
<td>38, 41</td>
<td>9, 10</td>
<td>26, 28</td>
<td>33, 37</td>
</tr>
<tr>
<td>Year 2015</td>
<td>42, 45</td>
<td>10, 11</td>
<td>29, 30</td>
<td>38, 45</td>
</tr>
</tbody>
</table>

Using the coal safety stock model and various data from all aspects of the consumption variance, with the help of SPSS software, we are able to calculate the coal safety stock for the "12th Five-Year" period, which is shown in the following table 3.
### Table 3. The 12th Five-Year period, various aspects of coal safety stock (unit:10000 tons)

<table>
<thead>
<tr>
<th>Year</th>
<th>Max</th>
<th>Min</th>
<th>Max</th>
<th>Min</th>
<th>Max</th>
<th>Min</th>
<th>Max</th>
<th>Min</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011</td>
<td>33241</td>
<td>34408</td>
<td>5123</td>
<td>5533</td>
<td>3422</td>
<td>3629</td>
<td>9491</td>
<td>10493</td>
<td>650</td>
<td>693</td>
</tr>
<tr>
<td>2012</td>
<td>34977</td>
<td>36087</td>
<td>5533</td>
<td>5915</td>
<td>3729</td>
<td>3920</td>
<td>10729</td>
<td>11624</td>
<td>707</td>
<td>746</td>
</tr>
<tr>
<td>2013</td>
<td>36630</td>
<td>38212</td>
<td>5915</td>
<td>6274</td>
<td>4013</td>
<td>4191</td>
<td>11838</td>
<td>12655</td>
<td>759</td>
<td>796</td>
</tr>
<tr>
<td>2014</td>
<td>38725</td>
<td>40224</td>
<td>6274</td>
<td>6613</td>
<td>4362</td>
<td>4527</td>
<td>12851</td>
<td>13608</td>
<td>808</td>
<td>843</td>
</tr>
<tr>
<td>2015</td>
<td>40712</td>
<td>42141</td>
<td>6613</td>
<td>6936</td>
<td>4607</td>
<td>4686</td>
<td>13790</td>
<td>15007</td>
<td>854</td>
<td>877</td>
</tr>
</tbody>
</table>

### 5. Conclusion

Coal safety stocks for various aspects during the "12th Five-Year" period derived from coal safety stock model, should be achieved. According to the actual situation in 2011, coal inventory level for the society as a whole is about 3.2 billion tons. The predicted level according to the model is 3.3 billion tons, slightly higher than the actual level. Taking into account the uncertainties, the model is relatively reasonable. During the "12th Five-Year" period, if coal stocks for various aspects can achieve the level mentioned above, then there will be a steady supply of coal. Coal safety stock model has provided an early warning to the coal industry. It is a new idea, but this model also needs to be adjusted and improved.

### 6. References


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