Assessing the Reviving Risks while using the Manufacturing Resource Planning system at agribusiness enterprises

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Abstract. The article proposes to use the mathematical apparatus of economic analysis' axiomatic theory for studying the reviving risks. Adapting of the reviving risks' evaluation method for simple global supply chains of financial and production relations of agricultural enterprises has been conducted. The methodical apparatus for measuring the logistic risks of optimal raw materials' and final products' stocks of agro-industrial enterprises has been provided. It is proposed to implement the offered models and methods into Manufacturing Resource Planning system, for rapid prevention and minimization of risks.

Keywords: Business Intelligence, Reviving, Manufacturing Resource Planning, Universal Logistics System, Simple Global Supply Chain

Key terms. Mathematical Modeling, Mathematical Model

1 Introduction

Reviving (supply logistics) for the enterprise of agro-industrial production operates on a principle of supply chain. This principle is related to transmitting the inventories, raw materials, ingredients, final products, finances, information and services through a network of suppliers, manufacturers, distributors, transfer companies and trade.

In a somewhat simplistic sense, the logistics chains consist of a supplier and a consumer [1] or a set of partners in production and commercial activity [2]. Such chains are presented as a structure that specifies all the links of material, financial and other flows.

The process of logistics management covers up the supply of raw materials, replenishment of inventories, monitoring the status of stocks in distribution network, calculation of the filling point, forming of supply, production and marketing links. In the US and Western Europe agribusiness enterprises, the MRP I (Material

Requirements Planning) [3] and MRP II (Manufacturing Resource Planning) information systems are used to manage logistics. As experts [4] point out, MRP II information systems today operate on-line with daily database updates.

The basis for building these productions, supply, sales and marketing Push-systems has become the RP (Requirements / resource planning) logistic concept [5].

The production schedule plays a major role in MRP II. It is regulated and controlled by the manufacturer within the production units of integrated formation. The MRP II system operates under uncertainty of the external environment, the probability to experience damage or lose a profit, possible failures and the threats of risks. Therefore, calculation of risks, including reviving of the marketing component, is an important component of assessing the enterprise's potential. Reviving risks are associated with the possible losses, while forming the stocks of agrarian raw materials by the industrial producer and promoting the final products at the markets.

The problem of measuring the potential risks of marketing activities is extremely relevant for agro-industrial food producing enterprises in terms of both − further economic analysis theory development, and practical significance. The relevance of this problem is first of all caused by the requirements of functional stability and profitability, as the basis for quantitative assessment of the of universal logistics systems' competitiveness.

The article proposes to adapt the mathematical apparatus of economic analysis' axiomatic theory [7] for assessing the reviving risks of agricultural enterprises. Adapting of the reviving risks' evaluation method has been conducted for simple global supply chains, and simplifies its implementation into the MRP II information systems of agribusinesses management.

2 Mathematical Approach and Modeling Technique

The risks of logistic supply cover up a many of initially uncertain factors. They include:

- changes in the optimal amount of raw materials' and final products' stocks;
- refusal or termination of the activities by intermediaries or investors;
- force majeure circumstances, caused by normative and legal issues;
- termination of raw materials processing, or their insufficient supply;
- change of sales law, caused by changes related to innovations in qualitative modification requirements, etc.

The effect of these factors is accompanied by a comprehensive reengineering of logistics chain's technological extension. It requires the use of a mathematical apparatus for describing logistic chains, impacts on them, and the dynamic changes in those chains.

The mathematical apparatus of the axiomatic theory of economic analysis (ATEA) has been used for further research [6]. Within the post-neo-institutional economic theory, the enterprise of agro-industrial production is viewed as a disjunctive set of simple and elaborate global chains of financial and production relations. These chains are the conservative structures. They are functionally oriented on producing and selling certain types of competitive products on the market [7].

The competitive situation arises (under axiom A.1 of ATEA [6]), when at least two universal logistics systems start operating on the global market. The diagram of the local chain of financial and production relations for such systems looks as follows:

$$B \xrightarrow{Y} A \xrightarrow{X} C \qquad (1)$$

where: B - is an agrarian enterprise, A - processing enterprise, C - commodity market, Y - raw materials, X - final product.

The agrarian enterprise B is a supplier of raw materials Y. Processing enterprise A is a consumer (partially or completely) of raw materials Y. It also sells final product X at the commodity market C.

The diagram (1) consists of two parts. Due to competition and force majeure circumstances, there is a there is a possibility of loss of some part of the market, which can be qualified as the risks of universal logistics systems' operation in the second part of the diagram (1).

Let's assume that some parts of the universal logistics system include a number of logistics risks. Distinguish the logistic risk of changing the optimal stock of raw materials and final products (LR1) among them. For a logistic risk LR1 the analytical apparatus for graphic research includes concepts and ratios, described in [8].

Let's take a look at competitive change in the parameters of M (optimal stock of raw materials), and T (time of stock turnover) the sales law (SL) M=P(T), when y=P(t), t>0. The change is made in the direction of reducing the parameter of M to $\overline{M}$ and, possibly, an increase of the parameter T to $\overline{T}$. After change, the sales law will look as follows: $\overline{M} = \overline{P}\left(\overline{T}\right)$.

Reduction of the parameter M is measured by:

$$\Delta\left(M, M_1\right) = \frac{M - M_1}{M} \cdot 100\% . \qquad (2)$$

It shows the percentage of the lost market share for the period *T*, i.e. $M_1 = \overline{P}\left(T\right)$.

Changing the sales law and measuring the lost market share are illustrated in the Fig. 1, a.

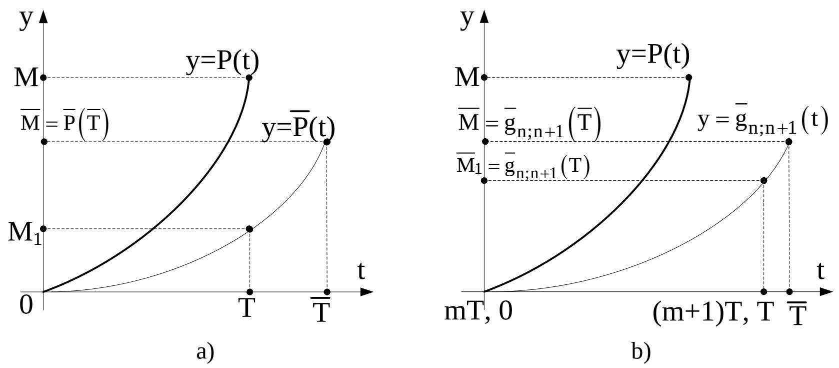

Fig. 1. Comparison of sales laws charts: a) initial y=P(t) and modified within the competitive changes of sales market conjuncture $y = \overline{P}\left(t\right)$; b) sales law y=P(t) at the last stage [mT,(m+1)T] and the law of supply $y = \overline{g}_{n;n+1}\left(t\right)$ at the first stage $\left[0;\overline{T}\right]$.

The maximal technological extension in explicit form (4) affects the change of the diagram (1). The diagram of commercial extension of financial and industrial relations' logistics chain looks as follows (5).

$$\{B_n, A*B_{n-1}, ..., A*B_1, A*B, A, C\}. \tag{3}$$

$$B_p \xrightarrow{Y'_p} ... \xrightarrow{Y'_{i+1}} A*B_i \xrightarrow{Y'_i} ... \xrightarrow{Y'_{j+1}} C*B_j \xrightarrow{Y'_j} ... \xrightarrow{Y} A \xrightarrow{X} C. \tag{4}$$

Expanding the logistic chain of financial, production, supply and distribution structures is carried out to enhance the synergy effect and reduce the logistics costs. Such changes will significantly affect the value added and the cost price of final products X.

It should be noted that in the simple global chain of financial and production relations of the agricultural enterprise (4) there is a sales law y=P(t), which is characterized by the initial parameters M and T. M – submission and α – submission of the product indicator X at maximum technological extension (3) look as follows:

$$M - R\left(\mathrm{ind}\, X/Y\right)_{tec} = \{M_n, M_{n-1}, ..., M_1, M, m(X)\}. \tag{5}$$

$$\alpha - R\left(\mathrm{ind}\, X/Y\right)_{tec} = \{\alpha(n), \alpha(n-1), ..., \alpha(1), \alpha(0)\}, \tag{6}$$

and at commercial extension (4):

$$M - R\left(\mathrm{ind}\, X/Y\right)_{tec} = \{M'_p, M'_{p-1}, ..., M'_1, M, m(X)\}. \tag{7}$$

$$\alpha - R\left(\mathrm{ind}\, X/Y\right)_{tec} = \{\alpha'(p), \alpha'(p-1), ..., \alpha'(1), \alpha'(0)\}, \tag{8}$$

In ratios (6) and (8), the transformation coefficients α (0) and α '(0) are determined by the equality:

$$\alpha(0) = \alpha'(0) = \frac{M}{m(X)}. \tag{9}$$

The power of reviving in a simple global chain of financial and production relations of an agricultural enterprise (3) is determined by the value:

$$\lambda_{rev} = \frac{f_{tec}\left(\mathrm{ind}\, X/Y\right)}{N_{tec}} = \frac{n_{tec}+1}{f_{tec}\left(\mathrm{ind}\, X/Y\right)+1}. \tag{10}$$

Let c'_k (k=0,1,2,…,p) – be the cost of raw material per unit in the state of k. In this state, the number of raw material units will be M'_k. C_X – the cost price per unit of the final product, taking into account only the Y component. Then the value added at each stage of the substance's transformation can be determined by equation:

$$\begin{cases} \Delta C'_{k-1} = C'_{k-1} - \dfrac{M'_k}{M'_{k-1}} C'_k, \ \ k = 1, 2, ..., p, \\ C'_0 = C_0, \end{cases}, \tag{11}$$

and in the elementary structure $\xrightarrow{Y} A \xrightarrow{X}$ - by the equation:

$$\Delta C_X = C_X - \frac{M}{m(X)} C_0, \tag{12}$$

Expressions, ratios and equations (2) – (12) should be considered within the TVS logistic methodology [6]. They are the basis for the analytical and graphic apparatus of quantitative risk assessment, related to the functioning of a simple or a branched global chain of financial and producing relations.

All further theoretical constructions will be conducted assuming that the diversification tendencies of the global sales market within the effective marketing policy in a simple global chain of agricultural enterprise's financial and producing relations (3) are predictable. Thus, it is possible to quantify the logistic risk LR1, related to the change of sales law from y= P(t) to $y = \overline{P}(t)$.

Let's assume that functioning of a simple global chain of financial and producing relations of an agricultural enterprise (3) within the current sales law y=P(t) stops at the moment of time, with further sale of an X product in the amount of M during the period [mT,(m+1)T] (fig.1,b).

Producing the X product in the amount of M within the new sales law $y = \overline{P}(t)$ starts at the moment of time t=mT. This results in a tonne-modification of given M- and α- product indicators of X ((3) and (4) accordingly). Modification is related to the replacement of the value M to $\overline{M}$. Reviving (supply logistics) also requires some changes that will affect all equilibrium and supply laws during $M \to \overline{M}$ and $T \to \overline{T}$ transitions. Note that the rebooting of a simple global chain of financial and producing relations (3) with the replacement of the sales law from y=P(t) to $y = \overline{P}(t)$ happens from the period t=mT. To this moment, every manufacturing enterprise A^*B_k (k=0,1,2,…n) has a raw material Y in the state of Y_k and in the amount of $M_k > \overline{M}_k$ with excess of stock $\Delta M_k = M_k - \overline{M}_k$. Regarding the sales law $y = \overline{P}(t)$, an enterprise has excess of stock of the final product (the surplus) $\Delta\overline{m}(X) = m(X) - \overline{m}(X)$. The system of redundant stocks of raw materials and final products looks as follows:

$$\left(\Delta\overline{M}_n, \Delta\overline{M}_{n-1}, ..., \Delta\overline{M}_1, \Delta\overline{M}, \Delta\overline{m}(X)\right). \qquad (13)$$

It is called the materialization of the investigated logistic risk LR1 of a simple global chain of an agricultural enterprise's financial and producing relations (3). It should be noted that information regarding supply laws $y=g_{n;n+1}(t)$ in the simple global chain (3) corresponds to the economic registration certificate (form ERC5), presented in [8].

The cost of the risk LR1 essentially depends on how the distribution function of the logistics management from the moment of time t=mT will be performed. To assess the risk LR1, let's look at two cases:

1. If the simple global chain of agricultural enterprise's financial and producing relations (3) will function according to the scheme (1), then the cost of risk LR1 should include the costs of long-term storage of excessive stocks (13) in the network of warehouses of processing enterprises (B_n,A^*B_{n-1},…,A^*B_1,B). Herewith, there is a transactional sales law y=P(t) acts during the last time interval [mT, (m + 1) T] of the conditions of the contract for the supply of final product X within the link $A \xrightarrow{X} C$.

Expenditures on producing the excess stock of finished product X in quantity of $\Delta\overline{m}(X)$ is calculated within the new sales law $y=\overline{P}(t)$ during the first time interval $\left[0;\overline{T}\right]$. As a result we received $\Delta\overline{m}(X)=\frac{1}{\overline{\alpha}(0)}\overline{g}_{n;n+1}(t)$, $\overline{g}_{n;n+1}(t)=\Delta\overline{M}\times$ $\times m_{n;n+1}\left((n+1)\overline{T};t\right)$.

2. If a simple global chain of financial and production relations of the agricultural enterprise (3) will function according to the scheme presented on (4), then the supply of final product within the sales law $y=\overline{P}(t)$ will start from the moment of time $t=\overline{T}$. There is a transactional sales law y=P(t) acts within the link $A\xrightarrow{X}C$ during the first time interval [mT, (m+1)T] and the contract for supply of final product X supply is being executed.

Thus, the costs related to the logistic risk LR1 will include the cost of maintaining the excess stocks (13), and expenses on producing the initial stock of final product in quantity $\Delta\overline{m}(X)=\frac{1}{\overline{\alpha}(0)}\overline{g}_{n;n+1}\left(\overline{T}\right)$, where, $\overline{g}_{n;n+1}(t)=\overline{M}m_{n;n+1}\left((n+1)\overline{T};t\right)$, $0\le t\le\overline{T}$.

In both cases, solving the issue of functioning of simple global chain of agricultural enterprise's financial and production relations (3) is related to the logistic risk LR1, and should take into account the presence of excessive stocks (surpluses) of raw materials and final products. These stocks exert financial pressure on the relevant global chain. In this situation, reducing the pressure on warehouses of manufacturing enterprises (B_n,A*B_{n-1},…,A*B_1,B), that store the above-mentioned excess stocks, is possible only taking into account the specificity of the functional schemes, presented in (1) and (3).

Unloading a simple global chain of financial and production relations of agricultural enterprise (3) and its transition to a stable functioning mode should be carried out in a spirit of reengineering. Reengineering modifies the global supply laws and actively uses the TVS methodology.

Let us give the examples of the corresponding schemes of unloading a simple global chain (3). For (1) at level $M-R\left(\mathrm{ind}\,X/Y\right)_{tec}$ and the time t, which fulfills the inequality $t\ge\overline{T}$ we receive:

$$\begin{aligned}&\left\{\overline{M}_n,\overline{M}_{n-1}+\Delta\overline{M}_{n-1},...,\overline{M}+\Delta\overline{M},\Delta\overline{m}(X)\right\}\to\\&\to\left\{\overline{M}_n,\overline{M}_{n-1},\overline{M}_{n-2}+\Delta\overline{M}_{n-2},...,\overline{M}+\Delta\overline{M},\Delta\overline{m}(X)\right\}\to...\ .\\&\to\left\{\overline{M}_n,\overline{M}_{n-1},...,\overline{M},\Delta\overline{m}(X)\right\}\to\left\{\overline{M}_n,\overline{M}_{n-1},...,\overline{M},\overline{m}(X)\right\}.\end{aligned}\tag{14}$$

For (3) from the moment of time $t\ge\overline{T}$ we have:

$$
\begin{aligned}
&\left\{\overline{M}_n + \Delta\overline{M}_n, ..., \overline{M} + \Delta\overline{M}, \overline{m}(X)\right\} \to \\
&\to \left\{\overline{M}_n, \overline{M}_{n-1} + \Delta\overline{M}_{n-1}, ..., \overline{M} + \Delta\overline{M}, \Delta\overline{m}(X)\right\} \to ... \qquad . \\
&\to \left\{\overline{M}_n, \overline{M}_{n-1}, ..., \overline{M}, \Delta\overline{m}(X)\right\} \to \left\{\overline{M}_n, \overline{M}_{n-1}, ..., \overline{M}, \overline{m}(X)\right\}.
\end{aligned}
\tag{15}
$$

The analysis of M- modification presents the product indicator X, relative to the raw materials Y (14) and (15). It shows that the transition of a simple global chain of agricultural enterprise's financial and production relations (3) to a stable functioning mode will happen accordingly for n+1 i n+2 time intervals, lasting $\overline{T}$. Herewith, in both cases, a simple global chain of financial and production relations of the agricultural enterprise (3) will undersupply the final product X to market C in an amount of $(n+1)\Delta\overline{m}(X)$ and $\overline{m}(X)+(n+1)\Delta\overline{m}(X)$ with the equal deficit in an amount of $(n+1)\left[\overline{m}(X)-\Delta\overline{m}(X)\right]$. It is obvious, that the cost of risk LR1 by the scheme (3) will be greater than by the scheme (1). Thus, direct losses of agro-industrial producing enterprises, integrated into a simple global chain of financial and production relations (3), for the period of their overload will be less, than $C_X(n+1)\left[\overline{m}(X)-\Delta\overline{m}(X)\right]$. This makes up a part of the cost of logistic risk LR1, without taking into account the cost of storing the excess stocks (13) in dynamics of their unloading.

3 CASE Study of Defining the Logistics Risk LR1 Indicators in the Supply of Raw Materials from the External Sources for LLC «Globinsky Meat Factory»

Let's see the example of calculation the risk in the logistic chains for Limited liability company (LLC) «Globinsky Meat Factory» [10]. The input data for the calculation was obtained from the internal sources (local enterprise accounting system based on Database Management System, DBMS), and from the reporting documentation of 2018.

The amount of annual processing of the meat factory is 300-310 thds. pigs. According to the industrial technology accepted by the enterprise, 5000 of them arrives for processing from two internal complexes of LLC «Globinsky pig complex» every 7 days (total of about 250 – 256 thds. per year. The rest of the livestock – 50-54 thds pigs the meat factory purchases from external sources. The raw materials from agricultural enterprises come for processing unevenly, in the amount of (M) and the time (T), therefore, a partial process of the livestock supply in a simple global chain of financial and industrial relations is susceptible to randomness. According to the internal reporting, a graph of the function X(t) was formed, describing the excess stock and shortage of raw materials for annual processing (Fig.2). When constructing a graph, it was considered that the meat factory has carried out the external purchases of raw materials during 260 days.

The average meaning of the function $\overline{X}(t)$ is a constant value. If a period when the demand for raw materials is not satisfied consider the refusal days and define them as n_1, then per year (n = 365) the assessment of the probability of supply failure P and the probability of risk-free supply − Q count as:

$$P = \frac{n_1}{n} = \frac{96+45}{365} = 0,386; \quad Q = 1 - P = \frac{n - n_1}{n} = 0,614.$$

The value of Q is called the reliability coefficient. Manager does not avoid the logistical risk LR1, but seeks to reduce it to a minimum level, by correctly determining the specified supply reliability of supply. If the rate of refusal is increased by a constant value (shown by a dotted line in Fig. 2), then the duration of the deficit will be limited to the time interval, supply reliability will increase.

While maintaining the amount of stock $M_k \geq \overline{M}_k$ at a certain normative level, it will correspond to some supply reliability $Q(M_k)$.

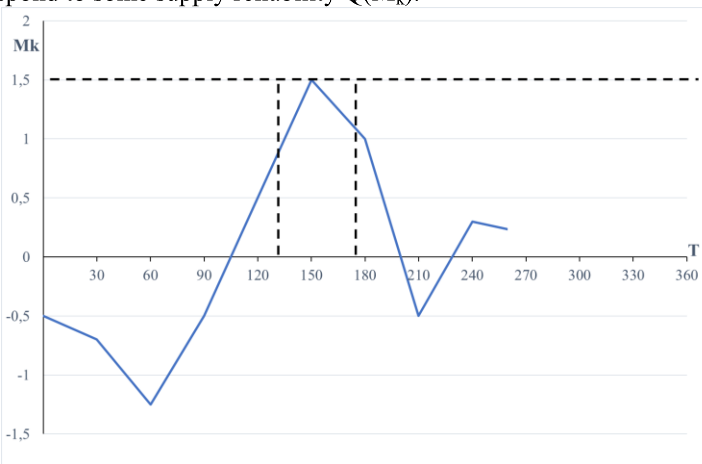

Fig. 2. Random changes in stock of raw materials of LLC «Globinsky Meat Factory» meat processing enterprise from external suppliers

The data from the reporting documents was used for further work. The SMIDA system [11] provides the following types of access to reporting data:

- direct access to tables and database records via API;
- access to web pages with reporting data with html-markup;
- access to reporting data in the form of a xml-document.

Common practice is placing the reporting documents in the form of pdf files, less often − doc/docx, on the enterprise’s web pages.

Thus, the use of the proposed model for estimating the reviving risks in the Manufacturing Resource Planning System provides the following data processing scenarios:

a) full data integration at the middleware, using the API;

b) partial integration, using middleware applications conduct parsing of web pages or xml-documents;

c) manual data integration, which requires preprocessing of downloaded reporting documents in pdf / doc / docx formats.

Depending on the chosen scenario, DBMS resources (calculated SQL queries), middleware applications or application software packages (MS Excel, MathCad, Matlab and similar) can be used to conduct calculations.

An example of calculation the risks in logistics chains of external sources of raw materials of LLC «Globinsky Meat Factory» is conducted in a manual mode, using the MS Excel table processor.

Meat-processing enterprise determined the risk conditions by three scenarios (A, B, C) of raw materials costs, obtained from the external sources. The excessive (beyond the norm), average and deficient purchases of raw materials are being presented (tabl.1).

Table 1. Risk conditions, depending on the daily cost of purchasing pigs in live (wet) weight of meat processing enterprise

Stocks of raw materials (Purchases)	The magnitude of the risk (probability of undesirable outcome)	Name of risk gradations	Raw materials costs under procurement scenarios (thds. UAH)		
			A	B	C
Excessive	0,1	Min	1100	1300	1500
Average	0,4	Avg	800	900	1000
Deficient	0,7	Max	400	500	300

As a result, the following absolute risk measures have been calculated: rank, mean absolute deviation, dispersion, standard deviation, variance and semi-variance. Additional indicators – semi-variance derivatives – deviation and coefficient of variation have also been calculated (tabl.2).

Table 2. The results of estimating the reviving of raw materials from external sources for LLC «Globinsky Meat Factory»

Absolute risk measures	Designation	The value of risk indicators LR1		
		A	B	C
Rank	R_g	700000	800000	120000
Expected average costs	$\overline{R}$	710000	840000	760000
Mean absolute deviation	MAD	142000	168000	152000
Variance	σ	85720	103520	225920
Standard deviation	ε	292,8	321,7	475,3
Semi-variance	SV	9610	46240	148120
Deviation, %	SV/ε^2	11,21	44,67	65,56
Coefficient of variation	ν	0,412	0,383	0,625

Thus, the risk level LR1 for partial purchases of raw materials from external sources for LLC «Globinsky Meat Factory, according to the coefficient of variation, is the highest in C logistics system. Such type of raw material supply scenario is not recommended to use.

4 Conclusions

The article uses the mathematical apparatus of the axiomatic theory of economic analysis (ATEA) [6] for quantitative measurement of the logistic risk of changing the raw materials' and final products' optimal stocks. The use of the proposed method allows reducing losses and measuring the lost market share, related to changes in sales stocks.

The structures and financial consequences of a simple global chain's of financial and production relations functioning, under emergence of a logistic risk, have been reviewed. The changes of the optimal stock of raw materials and final products have been researched. The results of the research can be used in MRP II information systems. It is an effective motivation for logistics management, as planning of the needs for productive resources allows enterprises to gain some benefits in improving the quality of their marketing potential (minimal levels of raw materials' and final products' stocks, and reducing the duration of the order fulfilment cycle). It also reduces the logistics costs of storing and maintaining the stocks, due to coordination of supplies within the logic chain. Thus, according to data [4,9], MRP II allows to reduce the amount of stocks by 17% (in terms of value), the costs of raw materials' purchase by 7%, as well as significantly increase the profitability of production.

The proposed estimation of quantitative measurement of a logistic risk improves the level of information systems' use, such as MRP II. This allows bettering meet the consumer demand by reducing the duration of production cycles and the time of raw materials' surpluses turnover, better supply organization, more efficient use of all kinds of resources, and to reduce the total costs' production, supply and sales.

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