A Mathematical Model for Optimizing Financial Flows in the Enterprise Innovation Processes

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***Abstract*— The current status of industrial enterprises in Russia, despite the objectives assigned for transition from the export and resource-based economy to innovative type of economy development, improvement of competitive advantages, development of domestic manufacturing under imposed sanctions, is characterized by low rates of innovative activity. One of the principal reasons for the current situation refers the challenges connected with efficient usage of own and loan funds directed into innovative activities, which are the area of high risks and require high profitability.**

For optimization of financial flows in innovative activities, we suggest using a mathematical model based on the method of financial flow framework. This model allows for estimating intensity of financial flows of an enterprise and the optimum amount of funds forwarded into financial flows of innovative activities. Additionally, the model allows us to reveal the dependence of reliability and profitability of investments on realization volumes of the outcomes of innovative activities, consider the risks, and define sensitivity of investments to the changes in the interest rates.

Keywords*— *mathematical model; method of financial flow structures; funds system model; intensity; duration; optimization

I. INTRODUCTION

Currently, development of the digital economy fuels introduction of IT technologies followed by reshaping the markets, by alteration in competitive environments, growth of uncertainty and risks, lowering financial capacities of enterprises of the real economy sector to encourage outward investments into innovative activities. Therefore, there is a growing demand for new methods of optimized utilization of own and loan funds covering financial flows in enterprise innovative activities.

In recent times, despite the government support to innovative entrepreneurship, the principal sources of funding include owned capital, rather than banks, venture funds and the so-called institutional sources. This follows from the growing uncertainty, risks, uncertain timing of returns and outcomes, including uncertainty relating the information needed for investors which results in decreasing innovative activities. Consequently, researchers activated their investigations into development of various methods for selecting sources of funding innovative businesses [2, 3, 4, 6, 12, 14].

One of the main problems discussed in the scholarly works is identifying the factors which influence the choice of financial resources [1, 5, 14, 16, 18], as well as amount of returns received both by an enterprise from individual sources and by investors [8, 9, 10].

A model for creating optimum financial flows in enterprise innovative activities can be effective in resolving the above mentioned problems. The given model is based on the method of financial flow framework and allows estimating not only risks, the needed intensity of financial flows in enterprises, and sensitivity of investments to the changes in the interest rates, but also defining the optimum amount of the required funds, and finding out dependence of investments reliability and profitability on the outcomes of innovative activities.

II. THEORETICAL APPROACH

The mathematical model for optimization of financial flows is created using the method of financial flow framework and is based on the industrial dynamics approach [7] adapted to the flow of enterprise financial resources. It is suggested to apply the method of financial flow framework in distribution logistics [17], and in creating financial plans and budgeting at enterprises [13, 15].

The mathematical model based on the method of financial flow framework has a set of advantages when used in the management of enterprise innovative activities:

- it helps in designing network models for financial flows in internal environments of enterprises;
- it helps defining an optimum relationship of financial, material and information flows;
- it allows for estimation and optimization of financial flows;
- it helps taking account of the time element;
- it enables developing effective strategies and plans for innovative activity growth;
- it allows forecasting and estimating risks.

III. CREATING A MATHEMATICAL MODEL BASED ON THE METHOD OF FINANCIAL FLOW FRAMEWORK

To create a model for optimization financial flows in the enterprise innovative activity based on the method of financial flow framework, we draw a graphical scheme where the flows are presented as continuous variables. Then, we define the di-

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rection and intensity of financial flows formed in accumulation units, which may have both positive and negative values. The positive value refers to the assets, whereas the negative value refers to the own and loan funds used for innovative activities. Since the assets and sources of funding must determine the balance, in the model it is presented as:

$$\sum_i C_i(t) = 0, \quad (1)$$

where *i* is the accumulation index.

Financial flows resulting from the enterprise innovative activity are formed due to the sales proceeds (BP_t), which in the model can be presented as the flow from ($З_t$) and the income flow ($П_t$)

$$BP_t = З_t + П_t. \quad (2)$$

Since the resulting income value can be accumulated for reinvestment into innovative projects, we observe its outflow from the earnings value. Therefore, the negative value in the accumulation unit constantly increases. The costs flow (3t) has the positive value by the end of the discount period, and the income flow Пt diverts on the lumpsum basis, which is reflected in the zero balance of the realization unit.

When forming financial flows in the enterprise innovative activity, the current assets include the current stock, costs, accounts receivable and cash. As a result, we receive the flows of the turnover cycle

$$П_{Цt} = Ц_{ед} \cdot К, \quad (3)$$

$$П_{ст} = С_{ед} \cdot К, \quad (4)$$

where К is the volume of commodity flows in innovative activities;

$Ц_{ед}$ is the price per unit of an innovative product;

$С_{ед}$ is the cost value per unit of an innovative product.

Additionally, financial flows in innovative activities include the production costs which are accounted for via a correlation of transaction prices and production costs:

$$П_{Цt} = Ц_{ед} / С_{ед} \cdot С. \quad (5)$$

The method of financial flows allows for analyzing the modes, intensity and sustainability of financial flow rates. An enterprise is characterized by sustainable performance if the intensity of the sales financial flow remains constant within a certain time span, i.e. Цt = const., as well as the production costs flow, and eventually will equal the costs flow

$$П_{Ц(t)} = П_{С(t)} = П_{З(t)} = const \quad (6)$$

Investment intensity, defined by the given expression, relates to the sales flow and can be called as the flow intensity in the turnover cycle. The flow value in the turnover cycle is characterized for the rate of the enterprise production load, which can be not too high due to limited capabilities of production capacities and distribution channels, or too low for economic reasons.

Intensity of the input influx of funds is determined as the amount of flows

$$П_t = П_{С(t)} + П_{АМ(t)} + П_{ЧП(t)}. \quad (7)$$

Since, in terms of an enterprise, the efficiency criterion for investments of the owner's funds into innovative activities is their profitability, then

$$Р^{СК}_{ИД_t} = П_{Цt} / СК \cdot Т \to \max, \quad (8)$$

where *T* is duration of the period;

CK is the enterprise internal funds invested into innovative activities.

Thus, in terms of the profitability criterion, there is an optimum value of the owner's funds used to create financial flows in innovative activities. When the value increases, the owner's funds are less effective due to restricted production capacities; when the value decreases, the returnsw rate of the owner's funds lowers due to insufficient funding of the full capacity operation in the turnover cycle. Moreover, selection of the given owner's funds determines the forecasted amount of sales resulting from innovative activities, the earnings, the amount of funds and their sources, and consequently, the value of the coverage ratio:

$$К_С = (З + Д) / И, \quad (9)$$

where З is the stocks and expenses;

Д is the cash flow;

И is the funds (own and loan) invested into the enterprise innovative development.

The model for optimization of financial flows in the enterprise innovative activity based on the method of financial flows framework can be described in terms of the minimum expenditures and maximum profits

$$\sum_{i=1}^{n} (N_i \times S_i) - \sum_{j=1}^{m} З_j \to \max \quad (10)$$

where is production of *i* items (units);

S_i is the wholesale price of an *i* item (RUB);

m is the amount of expenditure elements (units);.

$З_j$ is the costs related to j element (RUB).

As a rule, it is necessary to attract loan funds to finance the enterprise innovative activities. Therefore, it is important to analyze sensitivity of investments to the changes in the interest rates based on duration, which allows for estimating the average rate for components of investment resources with account for discounting costs, and depends on the structure of resources and the current interest rate

$$D = \sum_{i=1}^{N} C_i t_i / (1 + Y) / PV, \quad (11)$$

Generally, the characteristic of sensitivity to the interest rate is a change in the cost of investments under the changes in the interest rate by 1 basic point (PVBP) – 1%.

The exact result can be obtained using the modified duration and convexity of the payment flows

$$\Delta PV = -MD \times PV \times \Delta Y + 0,5 \times C \times PV \times \Delta^{Y^2} \quad (12)$$

IV. TESTING THE METHOD

The method for optimization of financial flows based on the method of financial flow framework was tested at the machine building enterprise in Saratov region, which has designed all-new parts to motor cars. Finally, a new scheme for the optimum amount of financial flows in the given innovation project dealing with production and sales of these parts has been worked out (Table 1).

TABLE I. ASSESSMENT OF FINANCIAL FLOWS IN THE ENTERPRISE INNOVATION ACTIVITIES BASED ON THE METHOD OF FINANCIAL FLOW FRAMEWORK

Indicators	First year	Second year
Flow rate in the cash cycle, kRIB	50566,1	9060,14
Net cash inflow, kRUB	3315	4680
Gross profit, kRUB	7505,3	9060
Net surplus, kRUB	2958	4176
Owned capital profitability, %	-15,72	14,72

Estimations conducted on the basis of duration rates allowed to determine that since the investments are made during the first year of the project, then the cost of investments does not depend on the changes in the interest rate (Table 2).

TABLE II. ASSESSMENT OF THE CURRENT MARKET INVESTMENTS COSTS BASED ON DURATION

Indicators	Value
Current investment costs, kRUB	27950,32
Duration of investments, units	1
Modified duration of investments, units	0,885
Dependence of the current investment costs on the interest rate changes, kRUB	-460,88
Convexity of investment flows, units	1,386

Additionally, when estimating the model for financial flows in innovative activities, we defined the funds utilization ratio, which helped to determine the following: if the sales flow intensity of innovative activity outcomes is at the maximum under existing own funds, then innovative activities are likely to grow evenly.

V. CONCLUSION

Thus, the method of financial flow framework allows for creating a model for optimization of financial flows in innovative activities taking into account their formation, utilization and risks connected with the need for recovery of the loan funds as soon as practicable, estimating financial solvency of an enterprise, and defining the potential and sufficiency of the owned capital invested into the given trend in the enterprise development.

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