Advances in Economics, Business and Management Research, volume 38
Trends of Technologies and Innovations in Economic and Social Studies (TTIESS 2017)

Analysis of financial effectiveness of economic-mathematical model of investment projects

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***Abstract*— To ensure long-term financial stability and enterprise sustainability, executives need a strategic approach in solving financial problems, in effective ways of investing and in creating models for investment analysis and forecasting. The offered mathematical model allows one to provide optimization of decisions in strategic management of investments. The technique of using several sources of financing as part of an investment portfolio is described. Various combinations of sources of financing for different terms of crediting are considered. There are different methods of making decisions on investment projects, based on the analysis of various criteria, which fall into two broad categories: conventional (not discounting) and discounting. The main function of the funds invested in the project is the generation of such cash flows which allow predicting the investment attractiveness of the project and efficiency. The author is interested in the dynamics of the cash flow generation process, which is ensured by the use of discounting. Investment projects have different qualitative and quantitative characteristics: financial, technological, organizational, temporary, etc. All of them are important, but financial assessments of investment policy are crucial in many cases. The author examines the criteria that are crucial for characterizing the investment process. The use of economic and mathematical models makes it possible to take into account various requirements, conditions, and to obtain variants of investment project scenarios. These criteria characterize the project's own effectiveness in generating cash flows, which is large compared to other weight criteria in proving project feasibility.**

Keywords*— mathematical model; investment sources; capital investments; objective function; payback time equation; payback period

I. Introduction

Financial management is concerned with the planning and controlling of the financial resources of the business firm [1]. The term “financial management” has emerged in the generic discipline of management [2, 3]. As an academic discipline, the subject of financial management has undergone radical changes in relation to its scope, functions and objectives [4].

In the past, the financial management was confined to raising of the funds and its procedural aspects. In the broader sense, it is now concerned with the optimum use of financial resources in addition to its procurement [5, 6].

Financial management provides the best guide for future resource allocation by the firm [7, 8]. It performs facilitation, reconciliation and a control function in an organization [9, 10]. It permits and recommends investment where the opportunity is greatest [11]. Financial management produces relatively uniform yardsticks for judging most of the enterprise’s operations and projects [12]. It is continually concerned with an adequate rate of return on investment, which is necessary to assure the successful survival of an enterprise [13].

The problem of attracting new capital and providing funds for capital needs is solved if the return on investments is adequate [14]. As it continues to draw attention to such matters, financial management is essential to effective top management [15].

Financial investments are necessary in operating the enterprise. Let us consider investment of funds from three sources of financing: bank loan, self-financing and state subsidies.

II. Results and Discussion

Let us introduce the notations:

Z – the amount to be invested in the enterprise;

S – annual planned income;

x_1 – the amount of bank credit;

x_2 – the amount of self-financing;

x_3 – the amount of state subsidies;

α – the ratio of the share (weight) of the bank loan;

β – the coefficient of the share (weight) of self-financing;

γ – the coefficient of the share (weight) of state subsidies;

T_1 – the time for which invested funds x_1 (bank credit) will pay off;

T_2 – the time for which invested funds x_2 (self-financing) will pay off;

T_3 – time for which invested funds x_3 (state subsidies) will pay off.

The author composed objective function Z (the sum of investments):

$$Z= \alpha x_1+\beta x_2+\gamma x_3 \qquad (1)$$

Restrictions on the use of the coefficients according to the rules of economic theory are:

(2)

Let us form the equation of time return on investment with bank loans:

$$T_1 = \alpha x_1+\beta x_2+\gamma x_3 S. \quad (3)$$

The author forms the equation of time return on investment using self-financing:

$$T_2 = \frac{\alpha x_1+\beta x_2}{S}. \quad (4)$$

There is the equation of time return on investment by using public subsidies:

$$T_3 = \frac{\beta x_2+\gamma x_3}{S}. \quad (5)$$

From equations (3), (4) and (5), let us form a system of (6):

$$\begin{cases} T_1 = \left(\frac{\alpha}{S}\right)x_1 + \left(\frac{\beta}{S}\right)x_2 + \left(\frac{\gamma}{S}\right)x_3 \\ T_2 = \left(\frac{\alpha}{S}\right)x_1 + \left(\frac{\beta}{S}\right)x_2 \\ T_3 = \left(\frac{\beta}{S}\right)x_2 + \left(\frac{\gamma}{S}\right)x_3 \end{cases}. \quad (6)$$

Let us solve the system (6) using matrix method and determine the utilization of bank credit (α), the utilization rate of self-financing (β) and the utilization of state subsidies (γ):

. (7)

Then one obtains:

$$\begin{cases} \alpha = S(T_1 - T_3)/x_1 \\ \beta = S(T_2 + T_3 - T_1)/x_2. \\ \gamma = S(T_1 - T_2)/x_3 \end{cases}$$

Since the weights are non-negative, let us introduce the system of restrictions on time T_1, T_2, T_3:

$$\begin{cases} T_1 \geq T_3 \\ T_2 + T_3 \geq T_1 \\ T_1 \geq T_2 \\ T_1 \geq 0 \\ T_2 \geq 0 \\ T_3 \geq 0 \end{cases}. \quad (8)$$

Based on objective data of banking practice, loans are currently issued for a period of 3 to 7 years. Let us solve the set task by a search method. The author will examine the coefficient of using bank credit (α), the coefficient of using self-financing (β) and the rate of using state subsidies (γ) for given T_1 (the time for which the invested funds are x_1 (bank credit)) and T_3 (the time for which the invested funds will recoup x_3 (state subsidies)). Let us find T_2 (the time for which the invested funds are x_2 (self-financing) will pay off) by putting T_1 and T_3 in system (8), and then substituting T_1, T_2 and T_3 into system (7).

1) Solving system (8) with T_1=3 and T_3=1, one obtains:

$$\begin{cases} 3 \geq 1 \\ T_2 + 1 \geq 3. \\ 3 \geq T_2 \end{cases}$$

Then two values of T_2 = 2 and T_2 = 3 are obtained.

Let us substitute T_1 = 3 (the payback period of invested funds x_1 (bank credit)), T_2 = 2 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidies)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(3-1)}{x_1} = \frac{2S}{x_1} \\ \beta = \frac{S(2+1-3)}{x_2} = 0. \\ \gamma = \frac{S(3-2)}{x_3} = \frac{S}{x_3} \end{cases}$$

T_1 = 3, T_2 = 2 and T_3 = 1 are not suitable, because the obtained α, β and γ do not satisfy inequality $\alpha \geq \beta$ and $\gamma \geq \beta$ in the system of constraints (2).

Let us substitute T_1 = 3 (the payback period of invested funds x_1 (bank credit)), T_2 = 3 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (the payback period of invested funds x_3 (state subsidy)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(3-1)}{x_1} = \frac{2S}{x_1} \\ \beta = \frac{S(3+1-3)}{x_2} = \frac{S}{x_2} \\ \gamma = \frac{S(3-3)}{x_3} = 0 \end{cases}$$

T_1 = 3, T_2 = 3 and T_3 = 1 are not suitable, because the obtained α, β and γ do not satisfy inequality $\alpha \leq \beta$ in the system of constraints (2).

2) Solving system (8) for T_1 = 5 and T_3 = 1, one obtains:

$$\begin{cases} 3 \geq 1 \\ T_2 + 1 \geq 3 \\ 3 \geq T_2 \end{cases}$$

One gets two values of T_2 = 4 and T_2 = 5.

Let us substitute T_1 = 5 (the payback period of invested funds x_1 (bank credit)), T_2 = 4 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidy)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(5-1)}{x_1} = \frac{4S}{x_1} \\ \beta = \frac{S(4+1-5)}{x_2} = 0. \\ \gamma = \frac{S(5-4)}{x_3} = \frac{S}{x_3} \end{cases}$$

T_1 = 5, T_2 = 4 and T_3 = 1 are not suitable, because the obtained α, β and γ do not satisfy inequality $\alpha < \beta$ and $\gamma < \beta$ in the system of constraints (2).

Let us substitute T_1 = 5 (the payback period of invested funds x_1 (bank credit)), T_2 = 5 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidy)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(5-1)}{x_1} = \frac{2S}{x_1} \\ \beta = \frac{S(5+1-5)}{x_2} = \frac{S}{x_2} \\ \gamma = \frac{S(5-5)}{x_3} = 0 \end{cases}.$$

T_1=5, T_2=5 and T_3=1 are not suitable, because the obtained α, β and γ do not satisfy inequality α<β in the system of constraints (2)

3) Solving system (8) with T_1=7 and T_3=1, one has:

$$\begin{cases} 7 \geq 1 \\ T_2 + 1 \geq 7 \\ 7 \geq T_2 \end{cases}.$$

Two values of T_2 = 6 and T_2 = 7 were obtained.

Let us substitute T_1 = 7 (the payback period of invested funds x_1 (bank credit)), T_2 = 6 (the payback period of invested funds x_2 (self-financing)) and T3 = 1 (payback period of invested funds x_3 (state subsidies)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(7-1)}{x_1} = \frac{6S}{x_1} \\ \beta = \frac{S(6+1-7)}{x_2} = 0 \\ \gamma = \frac{S(7-6)}{x_3} = \frac{S}{x_3} \end{cases}.$$

T_1 = 7, T_2 = 6 and T_3 = 1 are not suitable, because the obtained α, β and γ do not satisfy inequality α<β and γ<β in the system of constraints (2).

Let us substitute T_1 = 7 (the payback period of invested funds x_1 (bank credit)), T_2 = 7 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidy)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(7-1)}{x_1} = \frac{6S}{x_1} \\ \beta = \frac{S(7+1-7)}{x_2} = \frac{S}{x_2} \\ \gamma = \frac{S(7-7)}{x_3} = 0 \end{cases}.$$

T_1 = 7, T_2 = 7 and T_3 = 1 are not suitable, because the obtained α, β and γ do not satisfy in the system of constraints (2) the inequality α<β.

Analyzing the obtained solutions of the mathematical model, one has: with an increase in T_1 (the payback period of invested funds x_1 (bank credit)), the coefficient of using the bank loan increases, and at a constant value of the self-financing, it is possible to use coefficient β with the increase in T_2 (payback period of invested funds x_2 (self-financing)), Therefore, let us study the model for short-term loans for 1-2 years:

4) Solving system (8) with T_1 = 1 and T_3 = 1, one has:

$$\begin{cases} 1 \geq 1 \\ T_2 + 1 \geq 1 \\ 1 \geq T_2 \end{cases}.$$

Let us obtain two values of T_2 = 1

Let us substitute T_1=1 (the payback period of invested funds x_1 (bank credit)), T_2=1 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidy)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(1-1)}{x_1} = 0 \\ \beta = \frac{S(1+1-1)}{x_2} = \frac{S}{x_2} \\ \gamma = \frac{S(1-1)}{x_3} = 0 \end{cases}.$$

T_1 = 1, T_2 = 1 and T_3 = 1 are suitable, because the obtained α, β and γ satisfy the system of constraints (2).

5) Solving system (8) with T_1 = 2 and T_3 = 1, one has:

$$\begin{cases} 2 \geq 1 \\ T_2 + 1 \geq 2 \\ 2 \geq T_2 \end{cases}.$$

Let us obtain two values of T_2 = 1 and T_2 = 2.

Let us substitute T_1 = 2 (the payback period of invested funds x_1 (bank credit)), T_2=1 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidy)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(2-1)}{x_1} = \frac{S}{x_1} \\ \beta = \frac{S(1+1-2)}{x_2} = 0 \\ \gamma = \frac{S(2-1)}{x_3} = \frac{S}{x_3} \end{cases}.$$

T_1 = 2, T_2 = 1 and T_3 = 1 are not suitable, because the obtained a, P, and y do not satisfy inequality α≤β and α≤γ in the system of constraints (2)

Let us substitute T_1 = 2 (the payback period of invested funds x_1 (bank credit)), T_2 = 2 (the payback period of invested funds x_2 (self-financing)) and T_3 = 1 (payback period of invested funds x_3 (state subsidies)) and find α, β and γ:

$$\begin{cases} \propto = \frac{S(2-1)}{x_1} = \frac{S}{x_1} \\ \beta = \frac{S(2+1-2)}{x_2} = \frac{S}{x_2} \\ \gamma = \frac{S(2-2)}{x_3} = 0 \end{cases}.$$

T_1 = 2, T_2 = 2 and T_3 = 1 are suitable, because the obtained α, β and γ satisfy the system of constraints (2).

Thus, the optimal solutions of this mathematical model will be:

1) The self-financing use of factors $\beta = \frac{S}{x_2}$, where S is the annual revenue and x_2 is the self-financing amount in the absence of loans, which is achieved with time parameters T_1 = 1, T_2 = 1 and T_3 = 1. In this case, the objective function will have a value equal to S.

2) When using a bank loan, it is necessary that the coefficient of using a bank loan should be $\alpha = \frac{S}{x_1}$, where S is the annual income, and x_1 is the amount of bank credit and the coefficient of self-financing $\beta = \frac{S}{x_2}$, where S is the annual revenue and x_2 is the amount of self-financing that is achieved with time parameters $T_1 = 1$, $T_2 = 1$ and $T_3 = 1$. The objective function will have a value of 2S.

There are different methods of making decisions on investment projects, based on the analysis of various criteria, which fall into two broad categories: conventional (not discounting) and discounting. The main function of the funds invested in the project is the generation of such cash flows that will allow one to predict the investment attractiveness of the project and efficiency. The author is interested in the dynamics of the cash flow generation process, which is ensured by the use of discounting.

Criteria are based on the assertion that cash in the present is of lower value than in NPV and IRR.

Investment projects have different qualitative and quantitative characteristics: financial, technological, organizational, temporary, etc. All of them are important, but financial assessments of investment policy are crucial in many cases. Let us examine the criteria that are crucial for characterizing the investment process.

When the feasibility of adopting a particular project is assessed, three main questions arise:

1) What is the necessary amount of financial resources?

2) Where to find sources in the required volume and what is their price?

3) What is a return on investment?

Let us investigate the mathematical model for estimating these three basic questions.

Let us investigate the objective function obtained by the author:

Z= αx + βx + γx,

where:

α – coefficient of use (weight) of a bank loan;

β – coefficient of use (weight) of self-financing;

γ – coefficient of use (weight) of state subsidies.

In doing so, let us introduce a restriction that the amount of borrowed funds will not exceed its own, i.e. α + γ < β.

Let the self-financing coefficient have functional dependence $\beta = \frac{c}{\alpha+\gamma}$, where C = const. Let us investigate β under the following restrictions on the minimum:

$$\begin{cases} \alpha < \beta \\ \gamma < \beta \\ \alpha + \beta = 0.5 \\ \alpha \geq 0 \\ \beta \geq 0 \\ \gamma \geq 0 \\ \alpha + \gamma \leq \beta \end{cases}.$$

Let us study it with the help of the derivative:

$$\frac{\partial\beta}{\partial\alpha} = \frac{-c}{\alpha^2} \neq 0;$$

$$\frac{\partial\beta}{\partial\gamma} = \frac{-c}{\gamma^2} \neq 0.$$

Consequently, there is no extremum.

Let us find the conditional extremum with the help of the Lagrange function:

$$q = \alpha + \gamma - 0.5 \qquad L = \frac{c}{\alpha+\gamma} + \lambda(\alpha + \gamma - 0.5)$$

$$\begin{cases} \dfrac{\partial L}{\partial\alpha} = \dfrac{-c}{\alpha^2} + \lambda \\ \dfrac{\partial L}{\partial\gamma} = \dfrac{-c}{\gamma^2} + \lambda \\ \dfrac{\partial L}{\partial\gamma} = \alpha + \gamma - 0.5 \end{cases}$$

$$\begin{cases} \dfrac{-c}{\alpha^2} + \lambda = 0 \\ \dfrac{-c}{\gamma^2} + \lambda = 0 \\ \alpha + \gamma - 0.5 = 0 \end{cases}$$

$$\frac{-c}{\alpha^2} = \frac{-c}{\gamma^2} \to \alpha = \gamma \to \alpha + \gamma = 0.5 \to \alpha = \gamma = 0.25$$

$$\gamma = \frac{C}{0.0625}$$

M0 (0.25; 0.25)

$$H = \begin{vmatrix} 0 & -\dfrac{C}{0.0625} & -\dfrac{C}{0.0625} \\ -\dfrac{C}{0.0625} & \dfrac{2C}{0.0625} & 0 \\ -\dfrac{C}{0.0625} & 0 & \dfrac{2C}{0.0625} \end{vmatrix} = -\frac{2C^3}{0.25^7} - \frac{2C^3}{0.25^7} = -\frac{4C^3}{0.25^7} \leq 0$$

Consequently, point $M_0(0.25;\ 0.25)$ is a point of the conditional extremum.

Thus, self-financing ratio β has the smallest value equal to 0.5 of the required investment, equal to α = 0.25 of the loan amount and γ = 0.25 - of the public investment.

Let us calculate the payback period of the investments made. Let us suggest that the enterprise will receive an annual income of $S = \frac{1}{5}x$ from initial investment. First of all, the money will go to pay for the loan, which is 0.25 of the total investment:

The first year, the company pays the loan at the expense of its income: 0.25z – 0.2z + 0.17z = 0.22z, where 0.17z - interest charged by the bank;

The second year, all the income also goes to repay the loan: 0.22z + 0.22 * 0.17z – 0.2z = 0.0574z;

The third year, the enterprise fully pays for the loan – 0.0574z + 0.0574 * 0.17z – 0.2z = -0.1328z and begins to pay back its own invested funds: 0.5z – 0.1328z = 0.3672z;

The remaining part of own investments will pay off for 1 year and 10 months: (0.3672z / 0.2z) * 12 = 22.

Thus, taking into account the fact that subsidies are free, irretrievable transfer of funds from the budget to the legal individuals, let us calculated that with annual income $S = \frac{1}{5}x$ (that is, the income is of originally invested amount), the investment will pay off in 4 years and 10 months. In the case when it is necessary to recoup fully invested funds, including state subsidies, it will take 1 year and 3 months more, i.e. the investor will fully pay back its investments for 6 years and 1 month.

Let us calculate NPV project in terms of alternative investments - a bank deposit at 12% per annum for 6 years.

$$NPV = CF_0 + \sum_{i=1}^{n} \frac{CF_i}{(1+r)^i}$$

$$NPV = -x + \frac{0.2x}{1+0.12} + \frac{0.2x}{(1+0.12)^2} + + \frac{0.2x}{(1+0.12)^3} + + \frac{0.2x}{(1+0.12)^4} + + \frac{0.2x}{(1+0.12)^5} + + \frac{0.2x}{(1+0.12)^6} = -0.177x$$

NPV<0, therefore, the project is not profitable.

To make the project profitable, one will increase the planned level of income to 0.25 of the initial investment per year. Let us recalculate the payback period of the project:

First of all, the money will go to pay for the loan, which is 0.25 of the total investment:

The first year, the firm pays for the credit at the expense of its own income:

0.25z - 0.25z + 0.25 * 0.17z = 0.0425z, where 0.17z is the interest, charged by the bank.

The second year, the enterprise fully pays for the loan:

0.0425z + 0.0425 * 0.17z - 0.25z = -0.2z.

Then the company begins to pay back its own invested funds:

0.5z - 0.2z = 0.3z.

The remaining part of its own investments will be paid back in 1 year and 2 months and 12 days:

(0.3z / 0.25z) * 12 = 14.4.

Thus, taking into account the fact that the subsidies are free of charge, irrevocable transfer of funds from the budget to legal entities, the author calculated that with an annual income of S = 1 / 4x (that is, the income is equal to 1/4 of the originally invested amount), the investment will pay off in 3 years, 2 months and 14 days. In the case when it is necessary to recoup fully invested funds, including government subsidies, it will take 1 year more, i.e., the investor will fully pay back its investments in 4 years, 2 months and 14 days.

Let us calculate the NPV at a rate of 12% for 6 years:

$$NPV = -x + \frac{0.25x}{1+0.12} + \frac{0.25x}{(1+0.12)^2} + + \frac{0.25x}{(1+0.12)^3} + + \frac{0.25x}{(1+0.12)^4} + + \frac{0.25x}{(1+0.12)^5} + + \frac{0.25x}{(1+0.12)^6} = 0.028x$$

NPV > 0, therefore, the project is profitable.

Let us calculate the internal rate of return (IRR). This is a value of the rate of alternative attachments, in which NPV = 0 with the help of the package "Solver" excel:

Numerator (income)	CF	0.25	0.25	0.25	0.25	0.25	0.25
Denominator	$(1+IRR)^n$	1.1298	1.2764	1.4421	1.6292	1.8406	2.0795
Terms	-1	0.2213	0.159	0.1734	0.1534	0.1358	0.1202
NPV=	0						
IRR=	12.98%						

The internal rate of return (IRR) is 12.98%, which makes the project not very interesting for investors, because the rate has a value close to the rate on bank deposits.

Let us calculate the level of annual income CF to provide IRR = a) 50% b) 30% c) 20%.

a) IRR=0.5

Numerator (income)	CF	0.25	0.25	0.25	0.25	0.25	0.25
Denominator	$(1+IRR)^n$	1.5000	2.2500	3.3750	5.0625	7.5938	11.3906
Terms	-1	0.3667	0.2444	0.1630	0.1086	0.0724	0.0483
NPV=	0						

IRR=	50%						

b) IRR=0.3

Numerator (income)	CF	0.25	0.25	0.25	0.25	0.25	0.25
Denominator	$(1+IRR)^n$	1.3000	1.6900	2.1970	2.8561	3.7129	4.8268
Terms	-1	0.2923	0.2249	0.1730	0.1330	0.1023	0.0787
NPV=	0						
IRR=	30%						

c) IRR=0.2

Numerator (income)	CF	0.25	0.25	0.25	0.25	0.25	0.25
Denominator	$(1+IRR)^n$	1.2000	1.4400	1.7280	2.0736	2.4883	2.9860
Terms	-1	0.2500	0.2083	0.1736	0.1447	0.1206	0.1005
NPV=	0						
IRR=	20%						

III. CONCLUSION

Thus, the author has found out that the originally planned income of 20% of the initial investment makes the project unprofitable - NPV (at a rate of 12%) is negative. However, if one raises the level of planned income to 25% of the initial investment, then the project is profitable. The internal rate of return (IRR) is 12.98%, which makes the project not very interesting for investors, so the author calculated the amount of annual income (as a percentage of initial investments) with attractive rates of internal profitability (20%, 30% and 50%).

The use of economic and mathematical models makes it possible to take into account various requirements, conditions, and to obtain variants of investment project scenarios. These criteria characterize the project's own effectiveness in generating cash flows, which is large compared to other weight criteria in proving project feasibility.

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