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AGENT – BASED MODELING IN DECISION - MAKING FOR PROJECT FINANCING

Abstract. *Utility is a concept used by economic theory to characterize human decision-making. Project financing implies a complex decision-making process that is based on an agent's choice of financial sources. Selecting between various financing options is guided by risk and reward. These two criteria make up the value of each project financing option. The differences of value between options offering various utilities to the subject are the ones that set in motion the entire decision-making mechanism. The one that offers the highest utility is preferred to "homo oeconomicus". This is characterized by rational behavior, directed towards maximizing its utility and lays the foundation of the classical economic theory. Modern economic theories such as game theory or behavioral finance reveal different facets of human decision behavior. Agent-based modeling uses the synergy between the classical and modern theories to simulate decision-making process.*

Keywords: *Decision - making, agent-based modeling, strategic behavior, timing project evaluation.*

JEL Classification: C15, D81, D03

1. Introduction

This paper presents the empirical results of using agent-based modeling in a decision-making model used for financing an investment project. Decision is the act which turns strategy into reality during the interactions of agents in the economy. The model considers that the activity of an enterprise consists of both repetitive and unique processes. Repetitive processes are taking place regularly and supporting the entire activity of the single entity. These processes require a minimum level of intervention, and decisions of this type are not subject of this research. Despite regular ones, activities trying to achieve a single objective like an investment are unique. They are implemented through projects. Project management implies decision making aiming at achieving a unique goal in a limited period of time, with specific allocation of human or material resources to achieve that goal. The project, by its very complex structure, requires a more complicated decision-making process in contrast with the regular activities. Who is the agent faced with the decision of financing a project? This is the project manager responsible for the results achieved by the project.

In order to achieve a goal the project requires resources, materials and money that are accounted separately at the project level and quantified monetary in the project budget. Project's financial structure implies certain risks belonging to the type of financing source used. The phenomenon of risk of financial imbalance in the project has direct implications to the financial balance between revenue and spending, during implementation. The equilibrium of the project's budget is to be studied in dynamics because the synchronization between receipts and payments depends on their sequence in time. The premises of this research refer to the fact that the risk of imbalances on financial equilibrium on the project budget level is the one that guides the selection process of financing a project. This risk is directly influenced by time sequence and volume of spending and revenue indicators which in turn lead to losses or gains from the project implementation. The agent's decision referring to which source of financing is optimal for the project is guided by criteria of risk and reward. The agent's behavioral response to these two factors it is the one that guides the entire decision – making process.

2. The importance of using agent-based modeling

Classical economic theory is build upon agent's rational behavior oriented towards maximizing its utility. Modern theories like game theory or behavioral finance speak about agent's behavior that is guided by emotions while agent –based modeling theory reveals a type of "switching" behavior of an agent that adapts his decisions in response to the environment he is in. Agent-based modeling offers an alternative to the analysis based on equilibrium equations of economic phenomena, which is static, by analyzing variables in dynamics (Scarlat, 2005). Agent-based modeling is like a film that contains more information about the phenomenon studied than a photo. The difference that lies between the level of revenue and expenditure is the one that being a positive it ensures the long term equilibrium of a projects' budget, over time. An attempt to capture these changes of state through a global and unique value may show only a surface image of the phenomenon, which does not capture the dynamics of the steps that have succeeded in time.

The model uses the notion of economy as being made up of a high number of different agents (Kahneman 2009, Scarlat, Maracine 2008, Taleb 2007). Agents are individuals interacting with each others, permanently. They adopt different strategies according their objectives. Some target profit making in transactions with other agents. These are what economic theory calls "homo oeconomicus". They adopt a risk-averse behavior towards events that may reduce the profit desired.

Another class of agents is what game theory calls "homo ludens" (Bătrâncea, 2009: pp.163-194). They prefer to assume certain risks in transactions with other partners as they play "for the sake of the game." The third category of agents is constantly changing their strategies depending on the context (Bloomquist, 2004). Whether it's a financial loss or a gain, this category of agents constantly move from the category of "homo ludens" to that of "homo oeconomicus" and vice-versa according to their response to context. This form of adaptation to environment is called "genetic algorithm" (Scarlat, 2005). The concept describes the pattern of successive changes in the strategic behavior of the third category of agents called „" homo switch". The notion refers to a mechanism that is similar to genetic mutation. This type of strategy reflects the attitude towards risk and reward of most humans. This type of strategic behavior is specific to agents playing repetitive games characterized by Nash equilibrium in repetitive games (Rasmusen, 2000).

Table 1.Categories of agents in the economy

TYPE OF AGENT	RISK	OBJECTIVE
”HOMO OECONOMICUS”	Aversion	Gain
”HOMO LUDENS”	Appetite	Gain/ loss
”HOMO SWITCH”	Appetite/ aversion	Loss/ gain

3. Decision-making model – assumptions and objectives

The mechanism of the selection process of sources for funding projects managed by agents is the subject of the model described. It involves two subtasks, namely the comparative assessment of funding alternatives to be included in the model and the actual decision on the form of financing that will be used. The first step in the selection process refers to collecting information regarding possible ways to finance projects. Thus, there are five types of funding currently used by companies that were selected for inclusion in the economic model. These refer to bank credit, equity loan, subsidy, non-reimbursable grant and self-financing from projects resources or companies own profit (Tulai, 2007). The difference in the model between subsidy and grant refers to the fact that grant is accessed by private companies and a subsidy can be obtained by a public entity. The agent will make a comparative analysis between them and after that he will decide which option will be used to finance a particular project. The financing decision involves the completion of this process. The model described in this paper refers to the decision-making process based on selection criteria including risk and reward.

The purpose of the model described in this paper is to reveal an approach to systemic risk for financial imbalances in the project. This research studies the balance of revenue and expenditure in the project due to time synchronization between receipts and payments. Time factor entered into the equation is used to generate new indicators in the model, such as velocity of cost and revenue. Their role is to offer the necessary support for identifying risk of imbalances in the budget of the project. Therefore, risk of financial imbalance is studied in the dynamics of financial sustainability of the project as a phenomenon analyzed in successive stages of time. In this respect, the model is build by using agent-based modeling that captures the choice of agents in response to risk of financial imbalance. This generates a specific level of liquidity in the project. The empirical analysis of the model is done by the use of four study cases. The purpose of the analysis is to identify "risk areas" generated by the escalating velocity rate of revenue by superior velocity rate of cost due to the financing sources used. Capturing the differences of cost in the study cases examined is specific to the type of financing accessed. This is quantified in the model by "areas" bounded by the velocity of cost and revenue. This is called the „risk area" because it suggests a risk of financial imbalance when the velocity graphics of cost is superior to that of revenue. The dimension of the surface of „ risk area" is a warning sign to the project manager on the emerging risk of cost not being recovered from the revenue generated in the project. Classical modeling based on equilibrium equations is trying to capture an image of a state in time. Therefore, the analysis of the model in the „flow" of time is done in dynamics by using agent-based modeling.

4. Presentation of the indicators used in the model

The purpose of the model is to study the risk of financial imbalances in projects by analyzing the factors that lead to the emergence of risk due to synchronization levels of the velocity of cost compared to that of revenue. The figure below shows how the speed rate of cost (v_c) exceeds the revenue speed rate (v_v) and leads to an „area" bounded between the two velocities, which is a warning sign about the risk of imbalances in the budget of the project when the speed rate of cost is higher than the speed rate of revenue.

Derivation of cost (C) versus time leads to the velocity rate of cost (v_c). Similarly, the velocity rate of revenue in the project is the derivation of revenue (V) over time (W. Gellert et al., 1980). The budget balance equation is as follows:

$$C = V \tag{1}$$

The derivation of equation (1) versus time leads to the following formula:

$$\frac{\Delta C}{\Delta t} = \frac{\Delta V}{\Delta t} \Leftrightarrow v_{Ch} = v_v \tag{2}$$

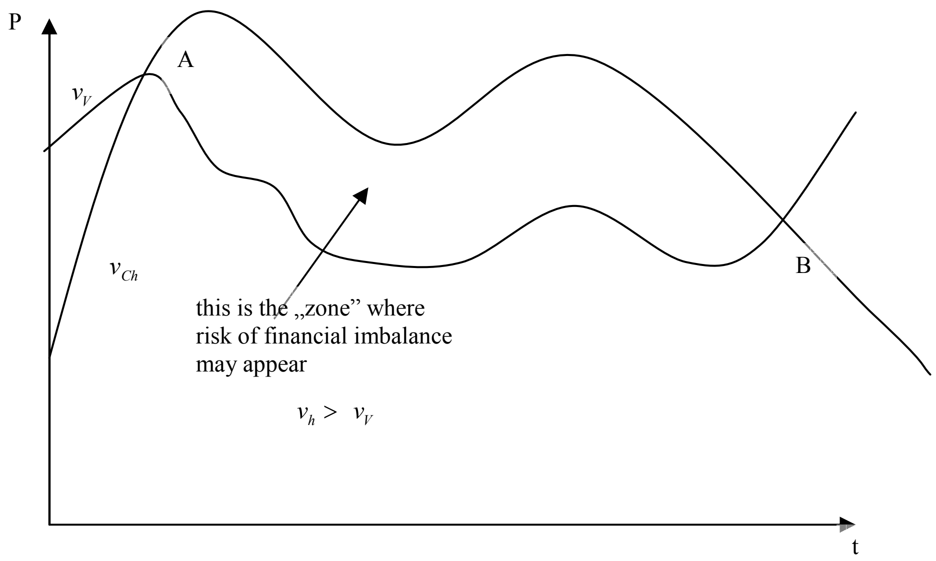

Figure 1. Representation of the variation of velocities of cost and revenue

Thus as revenue speed rate is higher than speed of cost reflects a favorable situation that can lead to the achievement of net profits in the budget of the project. Instead, when speed of cost exceeds the cost of revenue generated by the project this reflects a negative situation where the yield from the project is eroded by higher costs. The dynamic analysis of the model indicators targets a diagnosis of risk of financial imbalances in the equilibrium level of revenues and expenditure of a project. Risk criterion is important when the decision-maker must choose between various forms of financing for a project. Risk analysis follows a series of steps that describes the phenomenon from a quantitative and qualitative view.
The first indicator is the velocity of cost and it refers to changes made in project costs (ΔC), during periods of time equal to one year by the formula:

$$v_c = \frac{\Delta C}{\Delta t}, \Delta t = 1 \tag{3}$$

The second indicator refers to the velocity rate of revenue that captures the revenue variation (ΔV) to the budget of the project, during periods of time equal to one year. This is represented by the following formula:

$$v_v = \frac{\Delta V}{\Delta t}, \Delta t = 1 \tag{4}$$

The third indicator refers to the velocity rate of profit (v_π) which reflects the evolution in time of the deficit or surplus achieved by covering the costs incurred from revenue in the project's budget as follows:

$$v_{\pi}(t) = v_{v}(t) - v_{c}(t) \quad (5)$$

These indicators characterize risk in quantitative terms and are intended to identify the "areas" where risk may occur. The risk will be identified where there is a negative level of the velocity rate of profit through superior velocity rate of cost over the level of velocity rate of revenue. This "risk area" will be used in the analysis of projects' profitability or reward.

Risk is also assessed qualitatively by using the following indicators. The acceleration rate of risk is an indicator characterizing the likelihood of a financial imbalance in the equality of income and expenditure in the project's budget, at a point in time t and this is calculated as follows:

$$a_{r} = \frac{\Delta v_{\pi}}{\Delta t}, \Delta t = 1 \quad (6)$$

Secondly, the model associates a score to each category of the risk of financial imbalances in the project by a formula of average scores given by adding various levels of risk associated with different periods of time ($\sum_{t} \omega^{i} s_{r}^{i}$) and dividing them by the total number of periods. All in all, the risk of financial imbalances has the score S_r calculated as showed beneath:

$$S_{r} = \frac{\sum_{t} \omega^{i} s_{r}^{i}}{t} \quad (7)$$

Table 2. The types of risk of financial imbalance

Ref. no.	**Analysis of a_r**	**Profitability Dynamics*),**)**	**Type of risk**	**Risk scoring (S_r) (from 1 to 5)**
1.	$a_r < 0$ $a_r \downarrow$	Accelerated deficit growth	Maximum risk	5
2.	$a_r < 0$ $a_r \uparrow$	Deficit decrease	Medium risk	3

3.	$a_r > 0$ $a_r \uparrow$	Accelerated surplus growth	Minimum risk	1
4.	$a_r \geq 0$ $a_r \downarrow$	Surplus decrease	Low – medium risk	2,5
5.	$a_r > 0$ $a_r = ct$	Constant growth rate of surplus	Minimum – low risk	1,5
6.	$a_r < 0$ $a_r = ct$	Constant growth rate of deficit	High risk	4
7.	$a_r = 0$ $v_\pi \in (v_V, \infty)$	Constant surplus	Low risk	2
8.	$a_r = 0$ $v_\pi \in (-\infty, -v_c)$	Constant deficit	Medium - high risk	3,5
9.	$a_r = 0$ $v_\pi = 0$	deficit= surplus = 0	Null risk	0

* Surplus refers to the level of revenue above the level of expenditure.
** Refers to deficit when level of cost is superior to the level of revenue.

The risk of financial imbalances $R(t)$ is described using discrete values of the form $R(t) \in \{0;1;1,5;2;2,5;3;3,5;4;5\}$ corresponding to scores given according to the acceleration of risk is as follows:

$$R(t) = \begin{cases} 5 \Leftrightarrow a_r < 0 \wedge a_r \downarrow \\ 4 \Leftrightarrow a_r < 0 \wedge a_r = ct \\ 3,5 \Leftrightarrow a_r = 0 \wedge v_\pi \in (-\infty, -v_c) \\ 3 \Leftrightarrow a_r < 0 \wedge a_r \uparrow \\ 2,5 \Leftrightarrow a_r > 0 \wedge a_r \downarrow \\ 2 \Leftrightarrow a_r = ct \wedge v_\pi \in (v_v, \infty) \\ 1,5 \Leftrightarrow a_r > 0 \wedge a_r = ct \\ 1 \Leftrightarrow a_r > 0 \wedge a_r \uparrow \\ 0 \Leftrightarrow a_r = 0 \wedge v_\pi = 0 \end{cases}, \quad (8)$$

5. Using fractals in estimating probability of risk

The indicator of acceleration of risk of financial imbalances in the budget of projects can be used to estimate the probability of occurrence of financial imbalances in projects in an objective way. It can be quantified for different time intervals, less than one year or over 360 days. If time is considered as a variable which is used as a scale it can be noted that certain events take place in a similar regularity in time for both smaller and larger intervals of time (Liebovitch 1998, Scarlat 2005). Fractal characteristics of project finance risk managed by enterprises based on defining the rate of acceleration of risk reflects self-symmetry features at any time scale (Mandelbrot, 1983). Intuitively, the probability of risk of financial imbalance $p_R\%(t)$ characterized over the period of one year based on the acceleration of risk, reflects the probability of that risk $p_R\%(kt)$ at k t years by multiplying t by a constant of proportionality k (adapted from L. Liebovitch, 1998). The process can be described by the following:

$$P_R\%(kt) = kp_R\%(t) \tag{9}$$

Dimension „d" in the formula beforehand (adapted from L. Liebovitch, 1998) refers to the following formulation:

$$d = \lim_{t \to 0} \frac{\log a_r(t)}{\log(\frac{1}{t})} \tag{10}$$

Acceleration of risk provides an accurate probabilistic estimate of risk and is included in the function of estimating the probability of risk of financial imbalances is as follows:

$$P_R(t') = p_R(t)^d \tag{11}$$

where:

$$a_r(t) \wedge t = 360 \ \ days$$
$$d = \lim_{t \to 0} \frac{\log a_r(t)}{\log(\frac{1}{t'})}, \ \ t' \in (0,\infty) \wedge t \neq 360 \ \ days \tag{12}$$

The fractal dimension is „d" and it is dependent to the period of time used for estimating probability of risk of financial imbalances at project level. The formula is useful when estimating the risk of a time scale less or more than one year. A year is a time reference unit used to estimate the rate of acceleration of risk for projects managed by businesses. The value of „d" for one year is not defined because the denominator of the formula value is 0. Estimating the probability of risk for different periods of time beside a year, depending on the acceleration of risk goes beyond the subject of this paper and it could be subject of further research.

If one places the rate of acceleration of financial risk in project development on a coordinate system with time axis x, measured in number of years, and a probability scale on 0y reveals the following graphical representation of probability of risk.

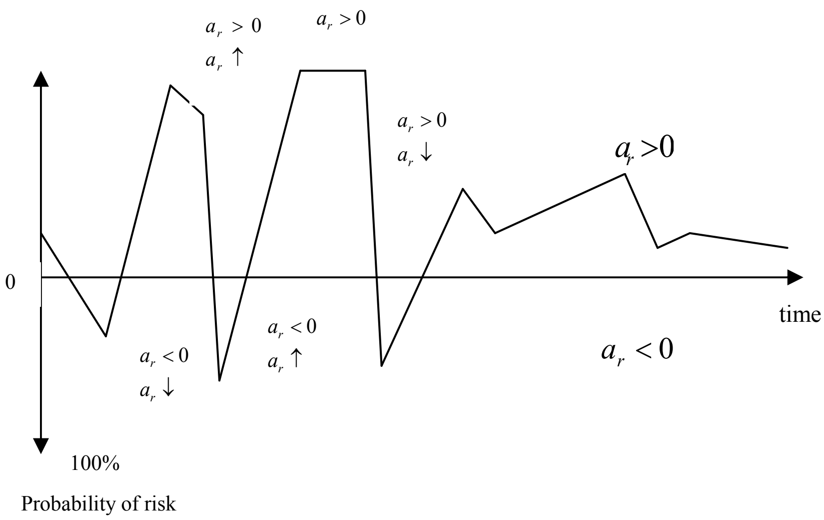

Figure 2. Representation of acceleration of risk

6. Dynamic analysis of indicators of profitability

The first indicator used to study the dynamics of profitability in projects is the surface of the area covered between the velocity rate of cost and revenue as a quantitative indicator of the level of profitability in a project. The surface of the „area of profit or loss" is calculated by the formula:

$$S_R = \sum_{t=1}^{18} \left(v_v(t) - v_c(t)\right)\Delta t = \sum_{t=1}^{18} v_\pi, \qquad \Delta t = 1 \tag{13}$$

The indicator can reveal two situations:

- The indicator value is positive when the velocity rate of revenue is superior to that of cost and in this case the project has a certain level of profitability.
- The indicator value is negative when the velocity rate of cost is superior to that of revenue, indicating a warning sign that the project could generates losses because the revenue generated by the investment made through the project is not enough to cover the expenses.

7. Applications of agent-based modeling

The model is based on the assumption that any investment materialized through a project may support a cost in its budget endurance limit according to the maximum capacity of revenue generated. An investment achieved through a project involves access to a range of financial sources by paying a price, which generates a cost that will be supported up to maximum capacity of an investment to generate revenue. In other words "any investor will finance a project up to the level at which he is willing to lose" (Trenca, 2005: p.15).
Modeling agents' decision involves the application of decision criteria on his assessment of financing alternatives for the project. The funding decision function of the agent is defined according to the formula:

$$F(x) = \begin{cases} 1 \Leftrightarrow x \geq 0 \wedge R(x) \in \{0;1;1,5;2;2,5;3\} \\ -1 \Leftrightarrow x \geq 0 \wedge R(x) \in \{3,5;4;5\} \\ 1 \Leftrightarrow x < 0 \wedge R(x) \in \{3,5;4;5\} \\ -1 \Leftrightarrow x < 0 \wedge R(x) \in \{0;1;1,5;2;2,5;3\} \end{cases}, x = \frac{\sum_t S_R}{t} \quad (14)$$

8. Results of the empirical analysis of the model

The empirical analysis of the model refers to testing a project with specific characteristics, on various forms of financing, each generating a specific cost for the project. The investment capacity of generating revenue and the operating cost of the investment are held constant along the analysis conducted. The comparative analysis of the four study cases carried out by testing an investment project through various forms of financing revealed a ranking of the four combinations of project financing risk and profitability criteria included in the source selection decision making model financing for investment projects.

Table 3. Prioritization of funding forms the basis of profitability and risk level for the probability of financial imbalance:

Nr.	**Study case**	**Type of risk**	**Risk score *(S_r)***	**Profitability (ΔS_z)**
1	EQUITY	Medium-high risk	3.44	100.899.242
2	GRANT	Medium risk	3.22	57.183.160
3	P.P.P.	Low risk	1.97	34.210.329
4	CREDIT	Low-medium risk	2.52	14.754.328

The decision-making process in the model is according to the type of agent. Therefore, the agent "homo ludens" will select to finance his investment project by equity loan because it offers him the highest degree of reward compared with other options but also the highest risk score of 3.44. This agent shows an increased appetite for risk in case of high gains. The second type of agent „homo oeconomicus" will choose the financing option of P.P.P. (public-private partnership) because it corresponds to the premises of his behavior described in the model. His selected option is characterized by the lowest level of reward and risk. The third type of agent "homo switch" can select any of the four combinations of financing. Such an agent is not designed to apply a certain criteria of profitability or risk to decision-making but he has other objectives than financial profits, such as social benefit or environmental protection.

9. Conclusions and future works

The conclusions referring to the empirical testing of the model reflect the way that a various combinations of financing a project can lead to different levels of systemic risk of financial imbalance at the level of a project budget. The element of risk and the reward gained are the two criteria used by the agent when deciding on financing a project. The present research shows that the agent's decision implying the financing of a project is not solely based on notions like utility or maximizing profit but also on level of risk that is connected to the reward obtained from the project. Another important aspect of the agent's choice refers to the nature of reward which is not just monetary but it can also have social or environmental content. The one aspect that makes the difference between the theories is the behavioral structure of the agent.

Unlike traditional analysis based on equations, agent – based modeling captures the oscillatory behavior of individuals in the interactions between them and their adaptation to environmental conditions. The present work lays a brick to the field of agent based modeling used for the study of decision-making process in the financing of a project. Further research will extend the application of the model to testing risk of financial imbalances in European projects due to the synchronization of payments and receipts which account greatly to the successfully implementation of the project and leads to a better absorption of European financing in the EU.

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