Model and dynamical assessment of innovative potential in the face of the rapid emergence of competing innovative solutions and the expansion of the global information space

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Abstract. The article considers the currently relevant issue of achieving the organization of advanced development. Since, as a rule, the innovative development approach is the basis for managing the development of an organization, which suggests the implementation of projects for the development and production of advanced development in an enterprise, the focus is on assessing the organization's innovative potential in the context of expanding the global information space. As a result of the innovation process carried out by the organization, there is not only the achievement of advanced development, but also the development of highly competitive products that form a new product market and radically change the existing market. Of course, to create a product that leads an organization to advanced development, it is necessary to have a number of resources and competencies discussed in the article. The example of the smartphone market, which characterized by a multidirectional change in the share occupied by the main manufacturers with similar innovative potential, is considered. As part of the mathematical model of Stackelberg, which describes the behavior of players in the oligopolistic market for high-tech products (as discussed in the article, the smartphone market), the game of several players-companies supplying their products to the market was considered.

1. Introduction

The result of any innovative process giving rise to a new kind of high-tech product market (i.e. rapid development of an organization) is successful development of highly competitive goods, which forms a new kind of product market or completely changes an existing one. An enterprise, which sells its products in an advanced product market, actually monopolizes it, and the product dominates it for a while [5]. According to the marketability theory, a product’s competitive ability is evaluated based on the technical and economical characteristics of a product dominating a market [1, 7]. High competitive ability of a product, as well as of its maker, is an indicator of a high innovative potential, which channels new and highly competitive products into the market [3]. Therefore, the concept of an organization’s innovative potential as applied to the conditions contributing to its rapid growth should be understood broadly as a group of growth drivers, which includes marketability, with consideration of all relationships and dynamics of change [6, 9]. This complex approach to evaluation of innovative
potential could form a criterion of the potential’s viability as a tool intended for reaching the goals of rapid development [10].

2. Methods
According to the theory of innovation, there are two types of it [2]:
- Process innovations visible through the improvement of technologies, which create a basis for design, production and modification of existing products.
- Innovations of goods that contribute to the appearance of new or modified ones.

The first type of innovation helps an organization to maintain its own and its products’ marketability. The effect from the implementation of such innovations lies in the possibility of increased output with amount of invested resources unchanged or the same output with a smaller resource investment (Fig.1).

![Figure 1. Resource/output ratio change resulting from the use of incremental innovation.](image)

In terms of resource production, this means an increase in the ratio due to a more pronounced technology factor $A$: $Y = A \cdot F(x_1, x_2, \ldots, x_n)$, where $A$ is the technology factor (it grows as innovations are implemented), $F$ is the resource production ratio, $x_1, x_2, \ldots, x_n$ are production factors.

The majority of such markets are not dominated by a company or product. The smartphone market (Fig. 2) is a bright example, as it shows a continuous divergent change in market shares held by major companies. Presumably, major smartphone manufacturers have similar innovative potentials. Competitive decisions, which briefly boost a manufacturer’s share in the market, are promptly adopted by other companies. Also, the diagram shows a gradual decrease in other manufacturers’ market shares. This signals that companies’ do not have the potential to compete with leader manufacturers.

Meanwhile, innovation has helped smartphone manufacturers to reduce prices for their products and increase sales.

The second type of innovation (goods innovation) focuses on the development of new kinds of products. There are several types of these products:
- New for markets, which are accepted by an organization as traditional ones. Such products can be created on the basis of innovations Type 1.
- New for the organization and never produced by it before.
- Products suited for absolutely new types of market, i.e. products of rapid development.

Definitely, to ensure stable economic development and growth (support) of an organization’s competitive ability, work should continue in all three directions. The effectiveness or the work in each direction depends on the organization’s innovative potential.

To provide a formal description of a company’s potential for reaching the rapid development status, there should be a description of an economic/mathematical model that would evaluate the sufficiency of a company’s innovative potential given the rapid appearance of competing innovative decisions and expanding global information space. The feature of this model is prediction of
prospective user expectations, sales, and new products’ market efficiency, which largely reflects the organization’s innovative potential.

**Figure 2.** Smartphone market dynamics (major manufacturers’ market shares from 1Q 2017 until 3Q 2018).

Characteristic of high technology spheres of economy is a situation resulting in the formation of oligopolistic high technology product markets. Several (usually, up to 10) manufacturers can sell their products within such a market. Each organization that is part of a market chooses and follows its own pattern of competitive behavior. An organization aiming at rapid development should follow a rapid development behavior strategy. This strategy implies prediction of competitors’ behavior and requires that the leader company monitor them and try to predict their reaction to other participants’ activities [4].

The mathematical model, which describes the behavior of high-tech oligopolistic market players, is based on the Stackelberg game-theoretic model. This game-theoretic model implies a leader-follower relationship between players. The disparity results from the difference between the players’ innovative potentials. According to the Stackelberg game-theoretic model, an organization, which boasts a higher innovative potential, should exercise the right of the leader. If there are a group of players (competing companies), an hierarchy is formed.

This game-theoretic approach to the building of a mathematical model implies that each player has a certain number of strategic decisions. The leader’s strategic decisions, given that the leader is aimed at rapid development, are expressed as \( x_i \in X \), where \( X \) is the set of strategies exercised by the organization intent on rapid development. Other participant’s strategies are expressed as a combination: \( y_i \in Y \), where \( Y \) is the multitude of strategies exercised by other players.

Players choose optimal strategies \((x, y)\) based on their priorities. The functions of payoffs (companies’ income) are expressed as: \( H_i : X \times Y \rightarrow R, \ i = 0, 1 \).

Inequality in the market in question means that the organization with a higher innovative potential and competitive ability enjoys a greater number of rights than other players. Therefore, we are going to focus on a hierarchical game pattern. Based on our suggestions concerning the leadership of a more commercially viable organization, it offers (establishes) its strategic decision expressed as \( x^* \in X \). Once the first player has chosen a behavior strategy, the remaining ones make their moves. They choose what they consider the most optimal strategy, which would ensure maximum sales profit: \( y^* \in Y(x^*) \).

The payoff (suggested profit) results from the solution of the next optimization task: \( H'_1(x^*, y^*) \rightarrow max \).

The first statement is supposed to be an established one. This raises a question, which is typical of the Stackelberg model and concerns the choice of an optimal decision for the leading player – the organization heading toward rapid development. The theoretic-game context implies that the
organization should be the first one to choose a strategy, which should be based on an advanced prognosis of other players’ choice of a strategy only. The optimal response function is:

\[ P(x^*) = \arg \max \{ H_i(x^*, y) : y \in Y(x^*) \} . \]

This formula makes it possible to demonstrate a mathematical model for the choice of an optimal decision for an organization aiming at rapid development: \( H_o(x^*, P(x^*)) \rightarrow \max \).

The game theory uses a concept analogous to the optimal decision - the equilibrium. The game situation is called “the situation of equilibrium” in cases whereby none of the players wins from deviating from the equilibrium strategy (subgame perfect Nash equilibrium). However, in the oligopolistic high-tech market in question, players exercise the leader-follower relationship pattern. Such situations are quite in keeping with the Stackelberg theoretical-game formula.

To implement the described economic/mathematical model, it is advisable to use a simulation model, which can provide optimal decisions as organizations choose between strategies presented in the market [8]. Also, simulation models do note occasional economic factors, which can influence sales.

The choice of strategic decisions is defined in the following way:

\[ H_o(x^*, \arg \max \{ H_i(x^*, y) : y \in Y(x^*) \}) \rightarrow \max . \]

The process of choice of a strategic decision (a decision, which lies in defining equilibrium quantities) can be described based on a particular type of oligopolistic market – duopoly, where two organizations sell their products. One of them is the leader claiming rapid development in the market.

In this situation, the leader aiming at rapid development should be aware that its choice of output volume \( q_0 \) will ensure that the follower will choose volume \( q^*_1 \). Thus, the leader should choose production volume based on the solution of the following optimization task:

\[ H_o(q_0, q^*_1) = \max q_0 (a - q_0 - q^*_1 - c_0) . \]

The peak point for this function is \( q_0^* = \frac{1}{2} (a + c_1 - 2c_0) \) with \( q^*_1 = \frac{1}{4} (a + 2c_0 - 3c_1) \).

Given the effect of rapidly changing external factors, payoff values may need to be corrected. There is an advanced methods of analysis of external factors - big data mining, as it analyzes data contained in the permanently expanding global information space. This analysis can reveal the main trends in the competitive environment and help predict technique and technology development vectors, as well as other companies’ activities.

Because the Stackelberg model is dynamic, it can be applied at any time and enables the choice of an optimal competitive behavior strategy.

The graphic picture of a market situation described by the model is shown in Figure 3.

Thus, the use of the competitive rapid development behavior strategy makes it possible to predict other players’ activities and the rapidly changing economic factors. This theoretic-game model has helped to predict the scope of product supply for each organization. The leader is free to choose a strategy that ensures its product’s domination in the market. Domination criteria may differ from nation to nation. For example, Japan (a global leader in the high-tech segment) has a law, which sets a domination threshold of 50% of the market volume. In the context of rapid development, surpassing this threshold by an organization may mean its transition to a rapid development status within the market.

3. Results

Based on the given simulation oligopoly model, it is possible to determine a company’s innovative potential sufficient for its reaching of the rapid development status, which should be observed in its products’ domination: \( q_i > A \), where \( q_i \) is the organization’s market share (the solution of the game based on the given simulation model), \( A \) is the threshold, upon surpassing which the product should be regarded as dominating.
Another sign of market domination and the sufficiency of its innovative potential for reaching a rapid development status is a firm’s ability to independently determine key market parameters, as well as to prevent other players from entering the market and curb the activities of the current players; within the given model, this can be achieved through the choice of an optimal strategy for competitive rapid development behavior.

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