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Synergy Effect in Innovative Activities and its Accounting in the Technological Competencies of an Enterprise

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Abstract:

The article deals with the interdependence of competitiveness, innovation, as well as levels of entrepreneurial and technological competencies leading to synergetic effects in the development of high-tech companies.

The authors describe a synergetic approach which allows finding effective ways of management of the economic systems functioning according to market conjuncture laws, as well as synergetic innovation strategy management.

The article analyzes the effect of synergy in innovative activities and highlights the importance of its accounting in the management of technological competencies of the enterprise.

Keywords: *Competitiveness, innovation, entrepreneurial competencies, technological competencies, synergetic approach, strategy of synergetic innovation management.*

JEL Classification: *O10, O14, O31, O35.*

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1. Introduction

When building a management system of unique technological competencies of high-tech enterprises, it is necessary to take into account various factors that affect their economic and innovative growth. Among such factors, it is necessary to choose those that have the greatest impact. In the contemporary innovation economy, the influence of aspects such as competitiveness, technological effectiveness, human capital asset, competency, and innovativeness is continuously growing. At the same time, there is no single approach in the definition of these categories, and it is empirically believed that these concepts are interrelated. For the purposes of the present study, it is necessary to determine a set of parameters characterizing the management of enterprises' innovative development. The unique technological competencies are selected as the main parameter; however, it is assumed that there are a number of related parameters mentioned above, which are not independent and have a significant synergetic effect.

2. Synergetic effect

Synergetic effects can provide a non-linear course of the investment project implementation process. In Chursin *et al.* (2011) Chursin *et al.* (2017) Chechurina (2005) Ponomareva *et al.* (2012) Bondarenko *et al.* (2017) it is proposed to evaluate the efficiency of investment projects in the context of transition to the industrial economy by the new economic category – synergetic efficiency. The synergetic efficiency of projects is a quantitatively measured result of intra-system interactions, reflecting the level of consistency, nonlinearity, ambivalence, as well as the effectiveness of positive feedback responsible for the development of the investment project in the field of innovation. For example, the synergetic efficiency of a project will be determined by the coordination of actions of scientific, industrial, financial, and business capitals along with support of authorities in the implementation of the innovative development strategy, as well as the most optimal use of resource factors of production (labor costs, raw materials and supplies, finance, etc.).

Consider the relationship of the main economic parameters (competitiveness, innovation, and competencies) in terms of their nonlinear relationship to achieve a particular economic effect resulting from creating competitive advantages based on the implementation of innovation, caused by the resulting synergetic (self-organizing) component as a result of the imposition of factors. In the most general form, the economic and mathematical model looks like this:

$$Q = f(K, L, M, T, N), \quad (1)$$

in this formula Q is some economic effect, K is the equipment (capital), L is the labor costs, M is the costs of raw materials and supplies; T is the technology used, and N is the entrepreneurial skills.

Within the framework of neoclassical economic theory, usually, *K* and *L* are used as independent arguments of the production function, which expresses the dependence of quantities of manufactured goods on the respective factors of production.

The influence of unique technological competencies on the economic growth of high-tech enterprises and industries is shown in the framework of the improved economic and mathematical model.

3. Synergistic innovations

Synergetic innovations can be based on cross-cutting technologies, technological platforms of enterprises, which are based on unique technological competencies (UTC). The essence of synergetic innovations consists in carrying out partial changes that allow the business entity to improve previously developed goods and services within the existing organizational structures and activity trends (Chemezov *et al.,* 2017; Egorova *et al.,* 2015).

Each synergetic innovation goes through stages of the innovation cycle such as innovation decision-making, implementation of innovation, changes in the economic system caused by innovation, and change of current developments. Consider the relationship of competitiveness, innovation level, and level of technological competencies in knowledge-based industries. For further research, it is necessary to select measurable parameters. Currently, a large number of competitions are held globally to determine the best innovative companies.

The ranking methodology includes different criteria for the assignment of a particular company to the Pantheon of the world's most innovative leaders. These criteria include: the amount of investment in R&D, difference between their market capitalization of the company and net present value of cash flows, patent data analysis, financial indicators, including sales volume, gross income, operating profit, and net profit, expert ranking, etc. (Tyulin *et al.,* 2015; Top 300 Patent owners, 2017; Sharaev, 2006; Kravchenko and Druzhinin, 2012; Bibarsov *et al.,* 2014).

It is interesting to note that to assess the effectiveness of the world innovative companies, none of the universal methodologies uses traditional factors of production, namely equipment or capital (*K*), labor costs (*L*), and the cost of raw materials and supplies (*M*). Innovative companies are characterized by other relevant factors, namely business and technical competence (Joseph Schumpeter), as well as key marketing, organizational, and technological competencies. The effectiveness of an innovative company is expressed differently for investors (profitability), consumers (new quality of goods), and society in general (level of technological leadership).

We consider competitiveness as the major characteristic of the integrated performance of an innovative company. The competitiveness of the company can be

assessed by various observed characteristics such as market share, occupied by its products, growth dynamics of its main economic indicators, etc. Competitiveness in knowledge-intensive industries is a complex economic category which can be considered at several levels: competitiveness of high-tech products, competitiveness of enterprises manufacturing high-tech products, competitiveness of knowledge-intensive industries, competitiveness of countries.

Competitive advantages of the company, which produces high-tech products, are provided in the course of the competitive struggle with other suppliers of similar products, companies, which are potential competitors, producers of substitutes and suppliers of resources necessary for the manufacturing of the high-tech product.

Today we can see in practice that the competitiveness of innovative companies is determined by a new set of basic parameters. The work "Mathematical model of the law on the relationship of unique competencies with the emergence of new consumer markets" by A.A. Chursin, R.V. Shamin, and L.A. Fedorova presents the economic law of interdependence of various parameters (*level of technological competencies, level of innovative technologies, level of new products, and the level of market development*), as well as shows their dynamics over time (Eremchenko, 2018).

Further, we consider the correlation and impact on the innovative enterprises' competitiveness of the certain factors, in particular, the UTC, because it is the UTC that is chosen as the control object in UTC control system and the major factor to provide innovative development of high-tech enterprises:

Competitiveness is a function of innovativeness, level of entrepreneurial competencies, level of technological competencies and quality of skilled labor, which is a combination of human capital asset and the level of technology achieved.

Consider the impact of these factors on the competitiveness, and most importantly, the interdependence of the function arguments, causing synergies. When constructing mathematical models, input variables are usually considered to be independent. The emergence of the interdependence of arguments can lead to the emergence of complex feedbacks. In control theory, it is known that strong positive feedbacks can cause powerful oscillatory cyclic processes, instability, and even uncontrollability of the system. Such behavior is demonstrated by economic systems under the impact of Schumpeter's creative destruction, where new products can destroy entire industries. Thus, the interdependence of factors may cause synergetic effects, which should be taken into account when managing economic systems. Therefore, testing the hypothesis of the interdependence of competitiveness factors is an important task of the study.

For the consideration, 30 companies from "The World's Most Innovative Companies" by Forbes were selected. Companies of non-technological business

sectors (such as eCommerce/Marketplace, On-Demand, etc.) were not included in the study. These economic factors were approximated by Forbes ratings of 2017 closest in terms of considered concepts: competitiveness was approximated by *Growth Champions* rating, innovativeness was approximated by the *World's Most Innovative Companies* rating, human capital asset was approximated by the *World's Best Employees* rating.

In addition, these companies were evaluated in terms of the number of patents and the dynamics of this number since last year according to the Intellectual Property Owners Association (IPO) (www.ipo.org). This information is interpreted as follows:

- Manufacturability is the number of patents obtained in 2016 (last year in terms of conducted rating);
- Competency (UTC) is interpreted as the relative change in the number of patents since 2015. Here it is assumed that the filing rate of technological patents, which is derivative of the manufacturability, is stipulated by the presence of the relevant UTC in the organization. The time shift to the study period (in fact, for 3-4 years, taking into account the terms of patent execution) takes into account the short innovation cycles of J. Kitchen, associated with delays in passing managerial information.

A comparison of the company ratings in independent Forbes competitions is presented in Table 1. The fact of getting the same companies in the different ratings is of interest, thus this fact already indicates the presence of synergy.

Table 1: *The status of innovative companies according to 2017 Forbes ranking Approximation of competitiveness factors*

Company	**Innovativeness**	**Competitiveness**	**Human capital asset**	**Manufacturability**	**Competency (UTC)**
1	2	3	4	5	6
Company	The World's Most Innovative Companies	Growth Champions	World's Best Employers	2016 Patents	Per cent Change From 2015, %
Salesforce.com	1	105	36	224	17,3
Tesla	2	42	277	380	35
Amazon.com	3	138	45	1663	46,3
Netflix	5	111	76		
Incyte	6	5			
Naver	9	197	132	360	30
Regeneron Pharmaceuticals	10	84	460		
BioMarin Pharmaceutical	12	110	127		

Company	**Innovativeness**	**Competitiveness**	**Human capital asset**	**Manufacturability**	**Competency (UTC)**
1	2	3	4	5	6
Adobe Systems	14			352	10,3
Amorepacific	16	164	275		
Red Hat	23	223	480	202	-20,5
Tencent Holdings	24	81	328		
FleetCor Technologies	25	107			
Nielsen	30			169	29
Ulta Salon Cosmetcs & Fragrance	34	140			
AmerisourceBergen	40	184			
Expedia	41	135			
Shimano	43			156	36,8
Global Payments	50	207			
Ctrip.com International	55	47			
TransDigm Group	57	194			
Booking Holdings	58	214			
Intuitive Surgical	61			126	14,5
Pandora	75	126	133		
Cerner	81	195	171		
Jiangsu Hengrui Medicine	82	191	242		
Boston Scientific	88			173	5
Procter & Gamble	89		136	397	-12,4
Fanuc	96			203	0
ASML Holding	100			225	-0,4

The ranking was carried out according to presented data with the subsequent determination of the Spearman's rank correlation coefficient (Table 2). For the analysis of the synergy effect of UTC it was chosen a cluster of science-intensive companies (1/3 of the total number with the highest level of UTC) what was approximated by the patent dynamics (in comparison with previous year).

Table 2: *Study of the interdependence of competitiveness factors*

Factors	**Spearman's rank correlation coefficient and qualitative assessment of the colligation degree by the Chaddock scale**		**Difference**
	Innovative leaders Forbes 2017	**1/3 of them with the highest level of UTC**	
Competitiveness – Innovativeness	0.481 Direct moderate correlation	0,885 Direct strong correlation	83,77%
Competitiveness – Human capital asset	0.056 No correlation found	0,258 Direct weak correlation	356,84%
Competitiveness Manufacturability	0.452 Direct moderate correlation	0,452 Direct detectable correlation	0,00%
Competitiveness – Competency	0.613 Direct detectable correlation	0,613 Direct detectable correlation	0,00%
Innovativeness – Human capital asset	0.216 Direct weak correlation	0,667 Direct detectable correlation	208,61%
Innovativeness – Manufacturability	0.361 Direct moderate correlation	0,826 Direct strong correlation	128,89%
Innovativeness – Competency	0.626 Direct detectable correlation	0,363 Direct moderate correlation	-41,99%
Human capital asset – Manufacturability	0.396 Direct moderate correlation	0,424 Direct moderate correlation	7,01%
Human capital asset – Competency	0.557 Direct detectable correlation	0,648 Direct detectable correlation	16,47%

The results show the existence of interdependencies of the function value with the competitiveness factors, as well as the correlations between the factors. There are clear prerequisites for synergistic effects.

The interdependence of entrepreneurial and technological competencies and their impact on competitiveness are considered as exemplified in fast-growing innovative startups, which have exceeded the capitalization of 1 billion USD, the so-called "unicorns". Table 3 presents 30 such companies. Non-technological business sectors, as in the previous example, are not included.

The following logic is used to approximate the competitiveness factors:

- Competitiveness is reflected by the achieved capitalization, given that it happened in record time;
- Entrepreneurial abilities are reflected by venture capital funding. In the contemporary literature it is noted that Schumpeter's entrepreneur of the 21st

century is a venture capitalist, who is looking for the possibility of combining factors of production to achieve a temporary monopoly, as well as investing "smart money", and is vitally interested in the success of the project;

– the UTC is approximated by the availability of technological patents. Given the high growth rate of "unicorns", this approximation is similar to the previous example in Table 3, namely "patents per time unit".

Table 3: *The 2017 ranking of the fastest growing startups with capitalization of more than $1 bln in 2017. Approximation of competitiveness factors*

Company	**Competitiveness (Capitalization)**	**Entrepreneurial ability (Venture investment)**	**UTC**
Company	***Latest Valuation, billion USD***	***Total Equity Funding, billion USD***	***Patents***
Uber	68.0	12.9	319
Xiaomi	46.0	1.4	854
Airbnb	31.0	3.3	25
Palantir	20.0	1.9	413
Pinterest	12.3	1.5	15
Lyft	11.5	4.1	15
DJI	10.0	0,576	397
Infor	10.0	2.6	6
Stripe	9.2	0,460	11
Grabtaxi	6.0	4.1	1
Magic Leap	6.0	1.9	356
NIO	5.0	2.2	49
Moderna	4.7	1.2	132
Fanatics	4.5	1.6	1
Houzz	4.0	0.615	6
Intarcia Therapeutics	3.7	0.813	62
Otto Bock HealthCare	3.5	0.790	50
Tanium	3.5	0.304	20
Bloom Energy	2.9	1.2	251
Unity Technologies	2.8	0.449	8
Oscar Health Insurance	2.7	0.753	1
Qualtrics	2.5	0.400	26
Domo	2.3	0.689	43
Github	2.0	0.350	7
Uptake	2.0	0.135	28
Sprinklr	1.8	0.275	14
Quora	1.8	0.226	21
ZocDoc	1.8	0.226	9
Klarna	1.4	0.299	8
Compass	1.0	0.210	29

Table 4: *Study of the interdependence of competitiveness factors*

Factors	**Spearman's rank correlation coefficient and qualitative assessment of the colligation degree by the Chaddock scale**		**Difference**
	The most growing startups	**1/3 of them with the highest level of UTC**	
Competitiveness – Entrepreneurial ability	0.842 Direct strong correlation	0,494 Direct moderate correlation	-41,26%
Competitiveness – UTC	0.321 Direct moderate correlation	0,716 Direct strong correlation	123,30%
Entrepreneurial ability – UTC	0.181 Direct weak correlation	0,037 No correlation visible	-79,38%

Table 4 shows the interrelation of all factors. Note that the strong correlation between "Competitiveness and Entrepreneurial ability" is, strictly speaking, due to the fact that a venture capitalist invests investment funds in a project, which is actually neoclassical capital (*K*). Venture investment is a vivid example of synergy, i.e. Capital + Entrepreneurial abilities. This explains the widespread success of this innovation mechanism. Analogously to the previous analysis a cluster of 1/3 of the total set of the studied companies with the highest estimation of UTC level (approximated by patent number) was also regarded. The moderate correlation of "Competitiveness – UTC" is due to the fact that most "unicorns" owe their success to the original entrepreneurial idea (Uber, Airbnb, Pinterest). It is clear that the dependence of the competitiveness factors shown here is the first approximation to a detailed study of the synergetic effects in the innovation development. Quantitative evaluation of these factors for the analysis is made indirectly through the available measured parameters. However, this allows us to qualitatively confirm the logically derived hypothesis of the interdependence between competitiveness, innovation, and levels of entrepreneurial and technological competencies (Grima and Sammut, 2017).

4. Synergetic approach

A synergetic approach to dynamics modeling is applied to the analysis of technical innovations. The group under the leadership of V. Ebeling (Humboldt University, Berlin) has obtained interesting results in the modeling of nonlinear dynamics of innovations in science. The Weidlich equation describing the macro configuration of innovation waves was used as the base model. Zang's work (1999) is based on Hagen's synergetic and focuses on nonlinear and unstable processes that characterize the behavior of some economic and mathematical models. In particular, the paper (Zhang, 1999) presents "Non-equilibrium model of Schumpeter clock". In Schumpeter clock model, when explaining fast non-equilibrium economic processes, the emphasis is made on the existence of active external microeconomic forces and a

strong deterrent and balancing effect on the supply side. The model is constructed based on microeconomic differences, i.e. on the heterogeneity of products and production processes. These differences begin to play a role at the lower level of the economic system (at the level of firms, markets, and industry). The formation of such differences is an objective factor in the investment strategy of entrepreneurs, who in accordance with their current intentions are divided into "expansionary adherents" and "innovators". Alternating shifts in the investment portfolio against investments of predominantly expansionary nature towards investments of predominantly rationalization type causes industrial fluctuations. In the course of the cyclical process, in search of monopoly profits, innovators and entrepreneurial pioneers capture leadership, acting in a direction opposite to the cyclical movement of investment strategies (Grima *et al.,* 2017; Bojare and Romanova, 2017). Synergetic analysis of complex non-equilibrium systems shows that the control parameters do not directly regulate the behavior of the control object but form an internal mechanism of its self-organization. In accordance with the topology of the structure-forming attractor area, the parameters of the non-equilibrium system behavior are set randomly, resulting in system's spontaneous move to a new level of organization, i.e. the system chooses the optimal way of its functioning.

However, despite its attractiveness and mathematical armament, noted approach has a number of disadvantages. In particular, the model does not take into account the role of unique technological competencies and their synergetic impact on the main neoclassical factors of production – labor and capital. It seems that the further research avenues should be related to the consideration of the synergetic effect of the UTC on the development of innovations in complex nonlinear economic systems as well as the development of recommendations for their management.

5. Conclusion

1. The article shows the interdependence of competitiveness, innovativeness, and levels of entrepreneurial and technological competencies that lead to synergetic effects in the development of high-tech companies.
2. The synergetic approach allows revealing effective ways of management of the non-equilibrium economic systems functioning under the laws of market conjuncture. This approach is focused on the knowledge of the self-organization patterns of complex objects in the context of chaotic spontaneous structuring.
3. The synergetic innovation management strategy is an interrelated set of actions aimed at strengthening the viability and economic stability of the enterprise with regard to competitors at minimal investment costs. The choice of such a strategy involves the creation of research and development plans, as well as other forms of innovation.

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