Evaluation of Uncertainty on the Stages of Business Cycle: Implementation of Quantum Principles

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ABSTRACT

The goal of the research is to propose implementation of quantum principles for evaluation of economic development on stages of business cycle, define the difference between traditional (deterministic) and quantum approaches and to provide quantitative analysis based argumentation for use of quantum economic principles in evaluation of internal and external factors on the stages of business cycle. The object of the study is possibility and reliability of quantum economic principles implementation to evaluate economic system performance. The authors analyze existing approaches towards implementation of deterministic, probabilistic and quantum models for estimating internal and external factors on stages of business cycle, define the benchmark for shift from traditional economy models and principles to quantum principles, describe the stages of business cycle from the quantum economics point of view and provide quantitative analysis of deterministic and quantum models quality on the level of enterprise to prove efficiency and reliability of quantum principles based approach. Calculations and data processing were carried out using Microsoft Excel and SSPS Statistics software.

Keywords: business cycle, quantum principles, quantum economics, model.

1. INTRODUCTION

Analysis of the main outcomes from the global economic crisis had revealed that existing prognosis models that are used for both macroeconomic and microeconomic indicators evaluation have relatively high range of margin, and this does not allow having an accurate idea for creating a strategy. This fact provoked a number of research initiatives and policy changes, and all of them are aiming to estimate the basic principles for internal and external factors evaluation in the modern economy – in order to provide accurate and reliable models for strategic and tactical evaluation of socio-economic environment dynamics.

One of the reasons for relatively low accuracy of existing economic model is the deterministic approach that is being implemented within them: despite the fact that socio-economic environment is a stochastic one, the models introduced to carry out prognosis are mainly determined factor type, or linear equations, and both of them do not allow to evaluate factors (especially the factors of social origin) that have high range of margin. The problem of modelling such processes is solved in natural sciences by introducing probabilistic models, or even models based on quantum principles that allow evaluating uncertainty as a factor defining dynamics of other factors' performance.

The problem of uncertainty as a key factor that affects socio-economic processes was stated by a number of economic scholars [2, 13], but the definition of this phenomena have stayed qualitative; and at the current state of economic system development evaluation of uncertainty seems to become an important element of modeling, as it was outlined by a number of scholars [15, 18]. Despite that, up to current economic models are mainly of regressive or multifactor nature and the uncertainty is evaluated by taking into account the probability of occurrence for a certain event. Existing practical evidence shows that reliability of such models is relatively low, and this fact indicates the need to look for an alternative approach in developing economic models.

Previously conducted research suggests economic models that evaluate uncertainty as a side, but not a key factor of development; at the same time quantitative analysis, provided by a number of scholars [6, 11, 26] proves that some of the trends are to be evaluated by using uncertainty factor as a key one. In this paper we aim to define the difference between traditional (deterministic) and quantum principles based approach towards economic modelling, and to provide evidence on advantages of using quantum based approach.

2. NATURE OF BUSINESS CYCLES: LITERATURE REVIEW

Theoretical approaches explaining business cycles were created on the basis of economic development retrospective data analysis and evaluation. Summarization of these approaches provided most common definition of business cycles: "Business cycles are a type of fluctuation found in the aggregate economic activity of nations that organize their work mainly in business enterprises; a cycle consists of expansions occurring at about the same time in many economic activities, followed by similarly general recessions, contractions, and revivals which merge into the expansion phase of the next cycle; this sequence of changes is recurrent but not periodic; in duration business cycles vary from more than one year to ten or twelve years; they are not divisible into shorter cycles of similar character with amplitudes approximately their own" [4]. According to this definition business cycles are non-linear and reflect diversity of economic development stages, its structure is viewed as a certain sequence of phases on the basis of retrospective data evaluation, duration of cycles and reasons behind changes of cycle stage have objective nature and there is some interrelation between different types of business cycles.

Analysis of existing literature on business cycles shows there are a number of theories that explain cyclic nature of economic development: starting from global level and ending with theories explaining business cycle of a single enterprise [13]. Provided explanations of business cycles' nature was summarized by Rothbard: "It should be recognized that most business-cycle theories – Keynesian, Marxist, Friedmanite, or whatever – and remedies are grounded in the assumption that the cycle stems from some deep flaw in the free-market economy" [22], and a list of reasoning for cyclic development of economic system include at least climate and geopolitics, demographics, social shifts, political shocks, discoveries and innovations, and changes in governmental policies and regulatory procedures, as well as a few other important reasons [13].

At the same time theories explaining business cycles tend to evaluate time as the main independent variable that defines business cycle stage and trend of development; on the basis of this parameter cycles were divided into 3 groups: macrocycles (that are hundreds or even thousands years in length, these are mainly social cycles such as proposed by Gumilev [12], mesocycles (lasting for several years or decades) and microcycles (these cycles last for days, weeks or months). Mesocycles include those of S. Kuznets [19] or the Schumpeterian "innovation lifecycles" [29] that can have duration from a year to several decades; another example of such cycles are Karl Marx's "cycles of main capital turnover" [21] that last for 50-60 years or Kondratiev's waves [18]. On mesolevel there were also a few attempts to estimate the relationship between military activity and business cycles as well as relation of business cycles to the industry dynamics, or to link value profile of society/enterprise and business cycles [9].

On macrolevel one can find Braudel cycles [16], which can be 150 years long, or logistic cycles lasting for 250 years or more [5]. On microlevel we can see a number of different cycles which mainly apply to a single company performance. From mid-XX century economic, social, political, and cultural cycles started to be viewed as a complex phenomena, which meant business cycles of different origin we supposed to complement one another. Henceforth complex synthetic models of cyclical socio-economic development were created [7, 8, 29] to integrate short-term and long-term socio-economic cycles – such approach is illustrated with a graph with multiple sine curves which include crisis, depression, recovery, and growth stages. Each stage has certain features that are repeated over time at the same stage in the next cycle – and thus existing research is imposing deterministic approach towards defining stage and perspectives of economic development on each stage of business cycle.

Existing literature suggests a number of reasons to explain socio-economic system dynamics on different stages of business cycle: some suppose that the sequence of stages depends on the level of systemic risk [14]; others propose that changing of the stages within a business cycle is related to changes in specific monetary policies [3, 30, 31] or define changes as consequence of volatility of money markets [27]. Gersbach and Rochet [10] and Lorenzoni [20] observe a correlation between economic and credit cycles, and Angeletos and La'O [1] found interrelation between informational frictions and stages of business cycle; North et al proves relatively significant institutional influence onto dynamics of countries' economic growth [21]. All of this findings, though shed some light on the nature of business cycles (and especially reasons that provoke crisis), still operate within space of determinism. At the same time existing research shows, that in the long-term period deterministic models that are used to create prognosis of trends of economic development has an average fluctuation of long-term prognosis lies in the range of 24-35%, which means these models are very limited. In our opinion, this is due to the fact that for model development a factor of uncertainty is ignored – and henceforth, creation of models that define socio-economic systems behavior on the stages of business cycle are to be based on the principles proposed by quantum theory in order to allow defining uncertainty as a key factor of economic development.

3. PROPOSITION OF QUANTUM PRINCIPLES FOR MODELLING ECONOMIC DEVELOPMENT ON STAGES OF BUSINESS CYCLE

Analysis of global economic system development in last 40 years shows that a number of fundamental principles of classical political economy, such as, for example, deterministic laws of supply and demand [11] do not explain facts provided by empirical evidence. This was outlined by a number of researches, who tried to develop an alternative model of economic growth on the basis of quantum principles [6, 22, 26, 28]; and on the basis of their research we make the following proposal: classical political economy is based on deterministic principles, while modern economy has a quantum nature – therefore main principles of classical theory are proven in modern world only with a certain probability.

Conversion point from classical to quantum economy is defined in our opinion by the ratio between the volumes of real and financial sectors of the economy: in case there is parity between those, the laws of classical economy operate; if these sectors are highly disproportional – the laws of quantum economics start operating. This can be formalized in the following way:

$$MV = PQ + \hbar * PQ = PQ * (1 + \hbar), \qquad (1)$$

where MV – the volume of stock of money and quasi-money (financial aggregates) corrected by the turnover speed of this total stock, monetary units; PQ – the volume of real sector of the economy, defined as a sum of goods and services produced, corrected by the price, monetary units; $\hbar$ – parameter, characterizing disproportion between financial and real sectors of the economy.

In case $\hbar$ defines excess of quasimonetary mass over real sector volume by certain number of times, the laws of quantum economics come into operation, and replace laws of classical economics, which are to be implemented before reaching this disproportion point. Introduction of $\hbar$ allows to explain contradictions which occur when laws of classical economics are used to structure statistical data, describing contemporary trends of economic growth and, also, the ones that come into focus when theories, explaining behavior of economic subsystems that belong to different levels.

Estimation of conversion point ($\hbar$ level), which characterizes the moment classical economy laws are replaced by laws of quantum economics, would allow to define the range of implementation for both theories: in the range of classical economy the laws explaining behavior of economic agents are determined (in this case economic parameters can be defined both for the current moment and in perspective), while behavior of economic agents in the realm of quantum economy is probabilistic (in this case economic parameters can not be strictly defined since they exist under uncertainty). For example, within classical political economy exists only one equilibrium price defined by determined supply and demand curves – while in quantum economy there would be *n* probabilistic supply and demand curves, and, as a result, *n* different probabilistic equilibrium prices. But for the certain time period and certain socio-economic system the factors affecting probability of different equilibrium prices can be defined, and probable combinations of supply and demand can be defined with a certain level of probability, which allows making predictions of economic agents' behavior in certain points of time-space continuum. Analysis of the time and spatial characteristics of the process which occurs within quantum economic system should be carried out by taking into consideration, that if spatial coordinate is fixed, timing coordinates increase to infinity, and vice versa – henceforth in quantum economics laws of classical economy can be formalized as well with implementation of probability characteristic.

This fact can be explain in the first place by the fact that basic economic equilibrium ($MV = PQ$) within quantum economic space is uncertain, and this uncertainty is provoked mainly by the uncertainty of stock of money and quasi-money in circulation within certain time period. Since volume of quasi-money (especially in case of derivatives market) can be derived from two characteristics – energy one (market value) and timing one (payment period) - fixation of each of the named characteristics within quantum economics space would lead to infinite growth of the other characteristic, and henceforth the main monetarist identity law can not be adhered in the fixed moment of time (due to infinite growth of stock of money and quasi-money). This thesis can be formalized in the following way:

$$\Delta M * \Delta t \geq \hbar \qquad (2)$$

where ΔM is the uncertainty of stock of money and quasi-money, monetary units; Δt – uncertainty of time stock of money and quasi-money is used.

In this case regulation of global economic system can be efficient only within a relatively significant time period, which has a proof in empirical data in terms of anti-cyclic regulation efficiency trends – and indirectly proves existence of both classical and quantum economy. Our qualitative research had shown that current state of global economic development can be considered as quantum one, and it can be derived also from the fact that deterministic models have a very high margin of error, while probabilistic models that are used in some sectors knowledge provide more accurate evaluations.

Within the proposed system the stage of growth in the business cycle becomes longer on each whorl of economic development. During this stage, there is economic space that is not filled, which leads to significant opportunities for entrepreneurs, that can be exploited. The features of this stage are booming economic growth, increased interrelations of the sub-autonomy subsystems that appeared during the recovery stage, and increasing boundary and currency exchanges. The financial sector is growing in accordance with increasing demand from the entrepreneurial sector. New economic formations provide additional opportunities for the use of new types of resources and create the conditions for higher intensity of resource implementation; the new economic formations also generate prerequisites for the creation of new technological solutions, which leads to further growth in entrepreneurial opportunities. During this stage, the growth of the entrepreneurial sector predominates and drags down the growth of the financial sector. By the time a socio-economic system has reached the middle of the growth stage, the economic growth rate begins to decrease. Another important feature is the gradual formation of an institutional environment that is adequate to meet the challenges created by the new economic formation; however, because the entrepreneurial sector is growing rapidly, the level of regulation is relatively low. By the end of this stage, the institutional environment becomes increasingly rigid, and economic space becomes more structured. Governmental interference at this stage should be limited to institutional development, which should stimulate higher intensity of resource use. Entrepreneurial activity occurs mainly in the formal sector, in which relatively loose institutional regulation does not erect significant barriers in terms of exercising entrepreneurial opportunities. Finally, it is notable that this stage is characterized by an innovation boom.

The stabilization stage begins when growth rates in the entrepreneurial and financial sectors even out. From this point, economic growth is ensured by the prevailing development of the financial sector, as new elements of monetary and/or quasi-monetary mass are developed or when the implementation of new technologies and qualified labor allows an increase in the turnover velocity of financial instruments. The entrepreneurial sector grows during the stabilization stage, but the growth rate is relatively low because the entrepreneurial sector is nearing its limit in this economic formation. The financial sector, by contrast, grows rapidly. Exchange processes within the socio-economic system are intensified, mainly because of increasing speculation, which is largely influenced by the relatively rigid institutional environment that now restricts entrepreneurial activity. Institutions become increasingly harsh; in some cases, institutional regulations appear even before prior to the creation of corresponding entrepreneurial activities. This rigidity leads to an increase in informal economy operations, which, in turn, provokes increasing institutional rigidity. Entrepreneurial activity and resources are driven to the financial sector, in which a high level of basic resource mobility prevents excessive rigidity in the institutional environment. The development of innovations becomes an expensive process, and it restricts entrepreneurial activity in the innovation sector, which results in the prevailing creation of quasi-innovations. The polarization of economic space gradually increases, mainly as a result of the concentration of financial activity at certain points of this space.

When the institutional environment becomes rigid, i.e., when the share of operations in the informal sector of the economy is in excess of one-fourth of the total amount of entrepreneurial operations and the cost of creating innovations begins to exceed the cumulative resources of a large enterprise, the recession stage is about to begin. The specific feature of this stage is a low rate of economic growth. The level of institutional rigidity continues to grow via the activity of multinational companies and supranational regulation. This leads to further growth in the entrepreneurial and financial sectors of the informal economy.

By the end of this stage, the informal economy has become larger than the formal economy, which means that the informal economy produces more than half of the services and commodities consumed in the socio-economic system. Innovational activity gradually decreases. The period of innovational development exceeds the visible planning horizon of a single enterprise, and the development of fundamental innovations becomes prohibitively expensive, partly as a result of the concentration of resources in the financial sector. The informal economy begins to produce its own institutional restrictions. This process is provoked by the approach of the maximum activity within the current economic formation, on the one hand, and by rapidly increasing expert power, on the other hand. Approaching the limitations of the current economic formation leads to abrupt growth in innovation-development costs and time consumption. If any fundamental innovations are created at this stage of the business cycle, they are typically products and technologies from the upcoming economic formation, and the development of technologies and materials required for a corresponding mass production becomes prohibitively expensive. The polarization of economic space continues to increase, and by the end of the stage, a tremendous share of the financial sector is concentrated within a few points of economic space. These points of concentration contain a significant share of the socio-economic system's monetary and quasi-monetary mass and provide conditions to increase the turnover velocity of these assets. Frequently, these points become the spots at which systemic economic crisis begins because the pressure of the financial sector on the entrepreneurial sector is extremely high at these points, which can cause the system to collapse. The economic energy released as a result of this collapse is retranslated to other points in the economic system, and the new recovery stage in the new economic formation begins. The change to a new economic formation is characterized by the collapse of both the institutional and financial systems from the previous business cycle. Recovery begins at the growth points that appeared before the collapse of the previous economic formation.

According to the model described above, the sequence of economic stages is not a function but a projection of the described multidimensional process on a time axis. The growth trend featured in this figure appears as a result of a change in economic formation. Henceforth, time is an independent variable that describes a process of business cycle movement for an observer but is not an independent variable that defines the structure or duration of stages within a business cycle.

4. PROPOSITION OF QUANTUM PRINCIPLES FOR MODELLING ECONOMIC DEVELOPMENT ON STAGES OF BUSINESS CYCLE

Proposition of suggested approach on the level of single enterprise means its external and internal environment are to be evaluated by taking into account uncertainty level. In order to use this approach we propose to evaluate resources as a key internal development factor of a company in the following way:

$$RES_i = res_i \sum_{k=1}^{q} res_{ik} \psi_{ik}, \qquad (3)$$

where RES_i – is amount of i-th resource of an enterprise that is available at a certain time point, monetary or non-monetary units; res_i – is the amount of i-th resource that a company possesses according to deterministic approach; ψ is a wave-type function that describes a state of res_i that is characteristic of state of resource used by a company at each point in time during the its existence; and k $(1\div q)$ is the number of unique states a resource could be found during a certain period. The wave function suggested implements Heizenberg's principle for socio-economic development, and allows to formalize a way to define uncertainty level at each stage of business cycle on the basis of internal and external environment evaluation (the latter means $\hbar$ also affects the type of wave function, and this indicator has a different value on each stage of business cycle – according to the stage of global development).

Implementation of this approach allows viewing enterprises' tangible and intangible assets not as a resource it can use when needed without any limitations, but as a source that can be used with different efficiency – and range of this efficiency can be only defined by implementing indicator that allows estimating level of uncertainty.

For the purposes of this research we have evaluated the data on efficiency of nine companies (both SME's and corporations from different sectors of industry: equipment building, oil processing, oil production, chemistry, telecommunications and services), which included pre-evaluation of resource efficiency – calculated as a ratio of profits (as EBITDA) to the summarized value of resource estimated – by both deterministic and quantum models, and efficiency that was found in fact three month after the pre-evaluation. For the purposes of this study we estimated efficiency of use for technical, technological, human, informational and financial resources; their value was estimated either on the basis of accounting data acquired within the enterprises, or we used estimations derived from expert opinions that were acquired by both questionnaire and interviewing.

The results of Pearson correlation analysis for technical and human resource efficiency are presented accordingly in Table 1 and Table 2. For all the other factors the results are similar to the ones provided in the Tables.

Table 1. Pearson correlation between deterministic, quantum and factual values of technical resource efficiency

		DTRE	QTRE	FTRE
Deterministic technical resource efficiency (DTRE)	Pearson correlation	1	,919**	,951**
	Value		,000	,000
	N	9	9	9
Quantum technical resource efficiency (QTRE)	Pearson correlation	,919**	1	,985**
	Value	,000		,000
	N	9	9	9
Factual technical resource efficiency (FTRE)	Pearson correlation	,951**	,985**	1
	Value	,000	,000	
	N	9	9	9
**. Correlation is significant at 0,01				

The data from Table 1 can also be illustrated in Figure 1. As it can be seen from the provided Figure, in case of technical resources efficiency estimation quantum-based approach is ensuring a better quality of prediction than deterministic approach, and in some cases the difference can be viewed as a very significant. This is not proven by non-parametric correlation analysis (in case of technical resources this type of analysis shows no difference between quantum-based and deterministic approach), but the existing graphical evidence proves that implementation of quantum approach allows to get access to more accurate data in perspective analysis. In terms of company planning, especially on the crisis level of company's business cycle, this might inspire important changes in firm development.

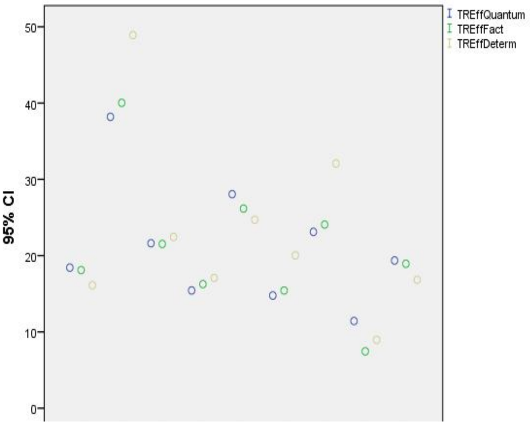

Figure 1. Errorbar for technical resources efficiency (deterministic, factual and quantum estimations)

Table 2. Pearson correlation between deterministic, quantum and factual values of human resource efficiency

		DHRE	QHRE	FHRE
Deterministic human resource efficiency (DTRE)	Pearson correlation	1	,902**	,908**
	Value		,000	,000
	N	9	9	9
Quantum human resource efficiency (QTRE)	Pearson correlation	,902**	1	1,000**
	Value	,000		,000
	N	9	9	9
Factual human resource efficiency (FTRE)	Pearson correlation	1,000**	,985**	1
	Value	,000	,000	
	N	9	9	9
**. Correlation is significant at 0,01				

As it can be seen from both tables (and similar results were acquired for other resources efficiency), the use of quantum principle based model using probabilistic approach provides more accurate prognosis.
This can be also proven by the results of correlation analysis for financial resources efficiency estimation (see Table 3).

Table 3. Pearson correlation between deterministic, quantum and factual values of financial resource efficiency

		DFRE	QFRE	FFRE
Deterministic financial resource efficiency (DFRE)	Pearson correlation	1	,947**	,950**
	Value		,000	,000
	N	9	9	9
Quantum financial resource efficiency (QFRE)	Pearson correlation	,947**	1	,994**
	Value	,000		,000
	N	9	9	9
Factual financial resource efficiency (FFRE)	Pearson correlation	,950**	,994**	1
	Value	,000	,000	
	N	9	9	9
**. Correlation is significant at 0,01				

The results of analysis prove, that quantum-based models provide better accuracy in terms of prediction of efficiency level, which proves the above achieved results and support the hypothesis the quantum based approach leads to a higher quality predictions than deterministic approach.
The same set of data was tested using non-parametric correlations, and the results were the following: for quantum model of technical resource efficiency estimation Kendall's tau-b was equal 1.000 (significant at 0.01) for Spearman's coefficient – 1.000; while Kendall's indicator for deterministic model appeared to be only .667, and Spearman's coefficient - .833 (all significant at 0.01). For human resource efficiency we acquired the following results: Kendall's tau-b was equal 1.000 for Spearman's coefficient – 1.000; while Kendall's indicator for deterministic model appeared to be only .556, and Spearman's coefficient - .717 (all significant at 0.01). For financial resource efficiency we acquired the following results: Kendall's tau-b was equal 0.944 for Spearman's coefficient – 0.983; while Kendall's indicator for deterministic model appeared to be only .722, and Spearman's coefficient - .850 (all significant at 0.01). So in this case the difference is even larger than in case of Pearson coefficient testing. Non-parametric correlation analysis for the variable with minimum range between factual, quantum and deterministic values is shown in Table 4.

Table 4. Non-parametric correlation between deterministic, quantum and factual values of informational resource efficiency

			DIRE	QIRE	FIRE
Kendall's coefficient	Deterministic informational resource efficiency (DIRE)	Correlation coefficient	1,000	,889**	,889**
	Quantum informational resource efficiency (QIRE)	Correlation coefficient	,889**	1,000	1,000**
	Factual informational resource efficiency (FIRE)	Correlation coefficient	,889**	1,000**	1,000
Spearmen coefficient	Deterministic informational resource efficiency (DIRE)	Correlation coefficient	1,000	,967**	,967**
	Quantum informational resource efficiency (QIRE)	Correlation coefficient	,967**	1,000	1,000**
	Factual informational resource efficiency (FIRE)	Correlation coefficient	,967**	1,000**	1,000
**. Correlation is significant at 0,01					

As it can be seen from the table, even in case of relatively small range of margin for the estimated variable (informational resources efficiency), non-parametric correlation for quantum-principle based estimation is higher than for deterministic model, that proves the quality of this type of models to be used for prognosis (even in case of low ranges quantum models have 1.000 correlation instead of .967 shown by Spearman correlation, and instead of .889 for Kendall's indicator). It also seems important that correlation between deterministic results and both quantum and factual results is the same, and shows the difference between the two approaches is significant.

Within the proposed research visualization of ranges of margin was carried out as well, and the results for financial resource efficiency can be seen in Figure 2 with the most picturesque errorbar for the resources tested within this research.

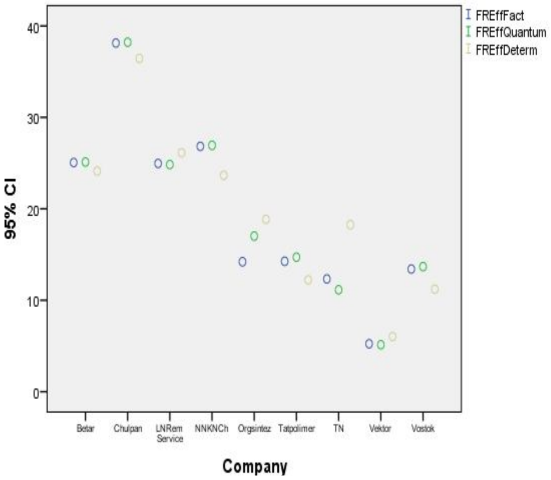

Figure 2. Errorbar for financial resources efficiency (deterministic, factual and quantum estimations)

As it can be derived form that figure, the level of error for quantum principles based estimation is relatively lower than in case of deterministic modeling of the indicator, and that also proves that quantum-based models are more reliable in case of determining the future value of certain internal factors. Similar shapes of the figures were acquired within graph analysis of technical, technological, informational and human resources efficiency evaluation, which allows to generalize the conclusion on higher accuracy of quantum principles based model relative to deterministic approach based.

The results acquired within this research allow proposing the necessity to use quantum principle based models for evaluation of internal and external factors defining behavior of an enterprise in the current economic environment. This can be explained by the fact, that traditional approach in economic modeling is using either pure deterministic models, either models considering probabilities of certain events, while quantum based approach offers another platform of modeling – by implementing density of probability instead of regular probabilities. This allows to acquire more accuracy in perspective planning and estimation of future values.

5. CONCLUSIONS

During analysis of possibility and reliability of implementing quantum principles to evaluate internal and external environment of an enterprise on the stages of business cycle we have come to the following conclusions:

1. Existing theoretical approaches towards evaluation of business cycles have the major limitation – they view time factor as an independent variable for evaluation of socio-economic systems performance on different stage of business cycle. This leads to wide range of cycles' duration even within one type of a cycle, and that proposes a conclusion that socio-economic system's performance is influenced not only by time factor.

2. Analysis of the contemporary socio-economic system structure (in terms of financial and real economy sector balance) shows that it significantly differs from the structure within which the basic principles of existing deterministic economy are developed, and thus evaluation of development trends in the modern economy are to be based on non-deterministic principles.

3. Investigation of uncertainty influence on socio-economic development drives a conclusion that quantum principles should be implemented for evaluation of its performance, since existing disproportion between financial and real sector do not allow to implement deterministic approach with necessary accuracy.

4. Estimation of enterprise's resource efficiency, carried out on the basis of both quantum principles (using wave function proposed by Heisenberg for evaluation of uncertainty) and deterministic based approach had proven that quantum based models provide more accurate results on micro-level. In case quantum principles are implemented for enterprise's performance evaluation, uncertainty level has to be defined by both macroeconomic uncertainty which is derived from the stage of macroeconomic cycle, and microeconomic uncertainty that has to be defined at the level of enterprise.

5. Implementation of quantum based approach which uses density of probability as a basement for perspective estimations, and such approach leads to higher accuracy in prognosis. This higher accuracy is a consequence of more reliable evaluation of uncertainty in company development, which can not be achieved if deterministic models, even with the correction by means of probabilities estimation, are implemented.

Several proposals and limitations of the study were made as the result of this research:

1. In order to improve accuracy of prognosis implemented at the company level a quantum based approach using wave function to evaluate uncertainty, should be used. This approach allows to decrease the range of error (that was proven by analysis of factual and predicted level of resource efficiency, which was carried out for a number of enterprises from different sectors of economy), and henceforth provides sustainable platform for decision-making.
2. Macroeconomic level of uncertainty has to be evaluated by estimating disproportion of financial and real sector of economy volume, certain level of which indicates shift from traditional (deterministic) economy to quantum economy.
3. Taking into consideration the number of cases analyzed to prove efficiency of proposed quantum principles based model for estimation of enterprise's future resource efficiency we need to take into consideration some limitations that arise from a small data sample that was used for the purposes of this study, which means results are to be tested additionally in future. The other limitation relevant to the mentioned one is the fact that enterprises tested came mainly from the real sector of economy, and results might appear to be different with the data from financial sector enterprises.

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