



Article

Modeling Changes in the Enterprise Information Capital in the Digital Economy

Dmitriy Rodionov *, Andrey Zaytsev , Evgeniy Konnikov, Nikolay Dmitriev and Yulia Dubolazova

Graduate School of Industrial Economics, Peter the Great St. Petersburg Polytechnic University, 195251 Saint Petersburg, Russia; andrey_z7@mail.ru (A.Z.); konnikov.evgeniy@gmail.com (E.K.); ndmitriev1488@gmail.com (N.D.); dubolazova_yua@spbstu.ru (Y.D.)

* Correspondence: rodion_dm@mail.ru

Abstract: The global COVID-19 pandemic has led to the self-isolation of people and the transformation of many economic and social processes into an electronic version thus contributing to the digitalization of all spheres. Being part of this environment, enterprises generate information resources to develop their desired image, which may vary according to the factors characterizing the information environment. Information capital is a comprehensive characteristic of an enterprise and determines its effectiveness and sustainability. The purpose of this study is to develop a toolkit that allows one to assess the information capital of an enterprise, reflecting its perception within the digital information environment. It is necessary to develop the methodology for the formation of such tools. As a result, a fuzzy-plural approach has been developed to evaluate the index of external information capital. This model allows us to assess the external information capital and to simulate its changes caused by various kinds of information events. The study of key elements, for example, the stability and tonality indices, index of target perception made it possible to systematize chaotic changes in the external environment and describe them using the Chen–Lee attractor model. The results of this study can be useful for researchers in the field of digital information analysis, in particular for the comparative analysis of enterprises and the assessment of their information capital.



Citation: Rodionov, D.; Zaytsev, A.; Konnikov, E.; Dmitriev, N.; Dubolazova, Y. Modeling Changes in the Enterprise Information Capital in the Digital Economy. *J. Open Innov. Technol. Mark. Complex.* **2021**, *7*, 166. <https://doi.org/10.3390/joitmc7030166>

Received: 25 March 2021

Accepted: 15 June 2021

Published: 29 June 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.



Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

Keywords: information capital; information environment; fuzzy logic; tonality analysis; stability analysis

1. Introduction

Over the past few decades, serious changes have taken place in socio-economic relations. In the era of post-industrial economics, material factors are no longer of the same high value for the enterprise as they were in the last century. Intangible elements, such as information, are becoming the main source of long-term development [1,2]. The effective use of classical factors of production is determined by applied knowledge, as described in Drucker's works [3,4]. Knowledge as a factor of production goes through three qualitative stages: the use of knowledge in the production process; the use of knowledge in labor and organizational activities; formation of new types of knowledge [3,4]. These stages have become the basis for the formation of intellectual capital, and the third stage highlights the importance of information in the creation of new knowledge, within the business entity and beyond it. Any business entity strives not only to take its place in the market but also to achieve leading positions with maximum returns, which is impossible without taking into account the dynamics of the external environment.

Information becomes the dominant factor that contributes to the development of protective mechanisms to counter external negative conditions. Information can also be used to obtain quality from existing corporate resources. The range of the use of information in the interests of the enterprise has no bounds. Every year, information flows become more extensive and it is almost impossible to control the external information environment [5]. The development of communication channels does not seem to be a complicated process,

since, in the era of digitalization, almost any person or company has access to information. The study of the information environment makes it possible to model the behavior of subjects and their response to changes in the information field.

In this study, we propose the theory of information capital, which is not developed yet in the scientific community. The concept of information capital can be viewed from various points of view. We introduce a new category called “external information capital”. This study considers the possibility of designing a toolkit for evaluating this type of capital by dividing it into three elements: vector capital, tonal capital, and stability capital.

The developed ability to manage external information capital will significantly increase the adaptability of the enterprise to external influences and unstable environments and create favorable conditions for an ensured increase in demand for manufactured products. The results of the study contribute to the development of the theory of information capital and can be used in related fields.

The purpose of this study is to develop a toolkit that allows one to assess the information capital of an enterprise, reflecting its perception within the digital information environment. The developed toolkit should be a set of mathematical models that allow the quantitative interpretation of the comparative properties of the information capital of an enterprise. It is necessary to study the theoretical basis for the analysis of the information environment of the enterprise and the assessment of its information capital. Then, we need to develop the methodology for modeling changes in the external information capital of an enterprise and develop the corresponding model. It is necessary to study the nature of the development of external information capital.

In order to fulfill these tasks, the authors have used a fuzzy-plural model for assessing the individual elements of external information capital and designed a model based on the Chen–Lee attractor to describe the interaction of these components and their mutual influence [6].

2. Literature Review

The information environment is unstable and creates both threats and opportunities. The development of the information environment is undergoing significant changes along with the transformation of social relations. Environmental fluctuations have a strong impact on the volatility of corporate information capital. Thus, even slight vibrations in the information environment, such as rumors and disagreements, can lead to a significant increase in the market capitalization, and even to the complete collapse of the company. The ability to manage information flows is becoming one of the main priorities in economic activity [7–9].

A striking example of the influence of information on the activities of business entities is the COVID-19 pandemic, which, just within a few months, triggered activities in the information environment that almost instantly affected all the actions of market players. Just a few years ago, external factors did not have such a serious consequence, which indicates the rapid development of information flows at the moment. The current situation makes it possible to develop behavioral algorithms that will enhance the adaptation and flexibility of the subject in the case that similar events occur in the future.

The intensification of digitalization leads to significant changes in public relations. Such a transformation necessitates a thorough study of the methods of survival and development of enterprises in new conditions. In order to succeed, any modern enterprise has to build up its intellectual resources, which are named “intellectual capital” in economics science [10].

In the scientific community, the concept of intellectual capital has been studied in detail, but its individual components have not been determined. Thus, the concept of intellectual capital is closely connected with many categories, which include information capital. Today, information is understood ambiguously, as it activates intellectual processes within an enterprise and external processes beyond.

The first works on the impact of digitalization on society were written in the 20th century [3,4,11–14]. The theoretical concepts considered by these authors led to the recognition of the priority influence of information on socio-economic processes. The theory of the information society has been put forward, according to which information flows have become one of the main factors determining the economic behavior of entities [15].

An important step in the perception of information as a production factor was its disassociation from information and communication technologies. The research in this field revealed that during the digitalization processes, a more generalized approach to information gradually developed, within which information is regarded as capital and the main way to gain strategic competitiveness [5,16,17].

Today, researchers distinguish five main characteristics of the information society: technological, economic, sociological, spatial, and cultural [18]. Thus, the processes of generation, circulation, and consumption of information have a huge impact on all areas of business and life. Information itself becomes an intangible resource that overcomes the barriers more easily than other resources, thereby becoming a conductor of globalization processes on a global scale [19,20].

Information processing and transmission technologies are becoming more intensive, which makes it possible to create a system for analyzing the transformation of information flows. Information has become the key source of competitiveness for business entities rather than just a specific resource in the context of Industry 4.0. Information and communication systems of corporate divisions allow us to evaluate information flows and build management and control models [21,22].

The study of methods, technologies, and tools for creating the enterprise's information architecture allows us to monitor the external environment and rationalize internal corporate information flows. Thus, information can help use material resources, labor, and capital more effectively which will open up opportunities for optimizing the economic activities of the enterprise [23].

The works [5,24] discuss the features of a stable position of an enterprise in the information environment. The authors propose information and communication technologies in the corporate environment. On the basis of this approach, we can consider information capital as an internal resource of an enterprise that is directly related to technological aspects.

In terms of investment, the implementation of projects to introduce specialized systems for managing information flows is an effective solution. This is primarily related to large enterprises with a sufficient level of goodwill and a popularized brand [25,26]. In the work of Ziemba [24], it is stated that managing the information potential of the enterprise and maintaining its quality at a high level can have a positive impact on the sustainability of the enterprise, while the expenditures on technological development alone do not bring such an effect. Unlike social scholars, academic economists mainly study the internal components of technological development. Undoubtedly, the internal information potential of the enterprise is vital for commercial success, while studying the influence of the external environment will allow us to get a deeper understanding of the enterprise position in the information field. Intellectual capital is the main source of sustainable development of modern enterprises in the innovative digital economy. The study of the influence of individual elements on the development of the enterprise will make the right choice of a strategy for economic development, taking into account both internal and external intellectual potential. Considering the external intellectual potential, we should pay attention to the client capital and goodwill of the enterprise. These indicators are under the direct influence of the information environment, as they make up the image of the company and affect the dynamics of its indicators.

According to some studies [27–29], information on technological development and technology transfer between enterprises has an impact on market capitalization and innovation. This fact confirms the importance of considering information to be one of the elements that can prevent a decline in the capitalization of an enterprise.

Considering the relationship between the information capital and the behavior of subjects in the external environment, it should be noted that the current process of social transformation is mainly due to the growing influence of the media, the social and technological development of the Internet, and the disclosure of data that were previously closed for users [30]. The intellectual potential of individuals studied in the work of Shipunova [31] has a huge impact on external information capital. The systemic impact of the digital information environment on the cognitive sphere of the subject forms its attitude to individual subjects, including enterprises. Studying the impact of mass online communication allows us to evaluate the attitude of individuals to the enterprise.

Since social instability and informatization influence the development of public opinion, specific knowledge, and demand for various goods, the information field has a serious impact on the intellectual status of the enterprise. The cost of intellectual capital can take both positive and negative values, depending on the prevailing information background. These problems were thoroughly studied in the work of Tikhomirov and Kalchenko [32].

An increasing number of modern researchers are considering the influence of external information flow on the results of the company's activities and the formation of new markets. I.B. Dolzhenko in his research concludes that thanks to the digital transformation of the economy, new markets for the distribution of goods and services have formed [33]. This development became possible due to the formation of fundamentally new groups of companies such as Amazon and eBay. The emergence of a new type of business has led to the transformation of the system of interaction with the consumer. The transformation of the internal environment of an enterprise under the influence of the information environment is considered in much more detail in [34], the authors established the significance of the influence of information capital of the enterprise on the quality of market cooperation, expressed in the increment of "network social capital". The results obtained are significantly supplemented in the study [35], the authors investigate the relationship between information capital and performance indicators of a manufacturing enterprise. The authors argue that a business process acts as an intermediary between information capital and the efficiency of an enterprise; it is the quality of business processes that allows this connection to be strengthened.

The information capital analysis process is closely related to semantic analysis tools. The information environment of an enterprise can be differentiated into two basic components—content component and tonal component. The content component is determined by the semantic content of the elements of the information environment dedicated to the investigated enterprise. From an applied point of view, the content component is a set of elementary content units of the information environment of the enterprise and their systemic sequence. An elementary meaningful unit is a token or a collection of tokens. Each token has a certain meaningful specificity that can be converted into a conditional value, relative to the enterprise. The tonal component determines the emotional color of the elements of the information environment. This emotional color is differentiated in accordance with such basic emotions as positivity, negativity, neutrality, and many others. At the moment, there are many automated tools for assessing the level of one or another emotional component in the general tonal component of the information environment [36].

It can be concluded that there is an ambiguous attitude to the information capital of the subject. Based on the analysis, it is proposed to distinguish the following approaches to its definition:

(1) Information capital is a combination of material resources, information systems, and other technologies of an enterprise. According to this definition, information capital can be both tangible and intangible. The tangible component is characterized by the computer systems available at the enterprise, and the intangible component is part of the intellectual capital realized in information systems and produced by human capital [10,37,38].

(2) Information capital is composed of all accumulated, renewable, and liquid information resources that contribute to the increment of potential or direct positive effects for the enterprise. Information capital is an intangible element that is concentrated both within

the enterprise and beyond it. Information is consumed by people, which increases the importance of human capital [16,39]. We deem this approach to be too abstract and hard to evaluate.

(3) Information capital also involves external indicators outside the company. In this approach, information is completely dependent on individuals in society. An individual is considered to be the main consumer of information and its qualitative characteristics predetermine his opinion about the subject. The behavior of an individual is determined by an array of macroeconomic factors that are virtually beyond the control of the enterprise. Therefore, the enterprise must customize its strategies depending on the information field that affects people. This approach is not thoroughly studied by researchers, and we suggest that it should be given more consideration.

Figure 1 illustrates the relationship of intellectual capital with internal and external information capital.

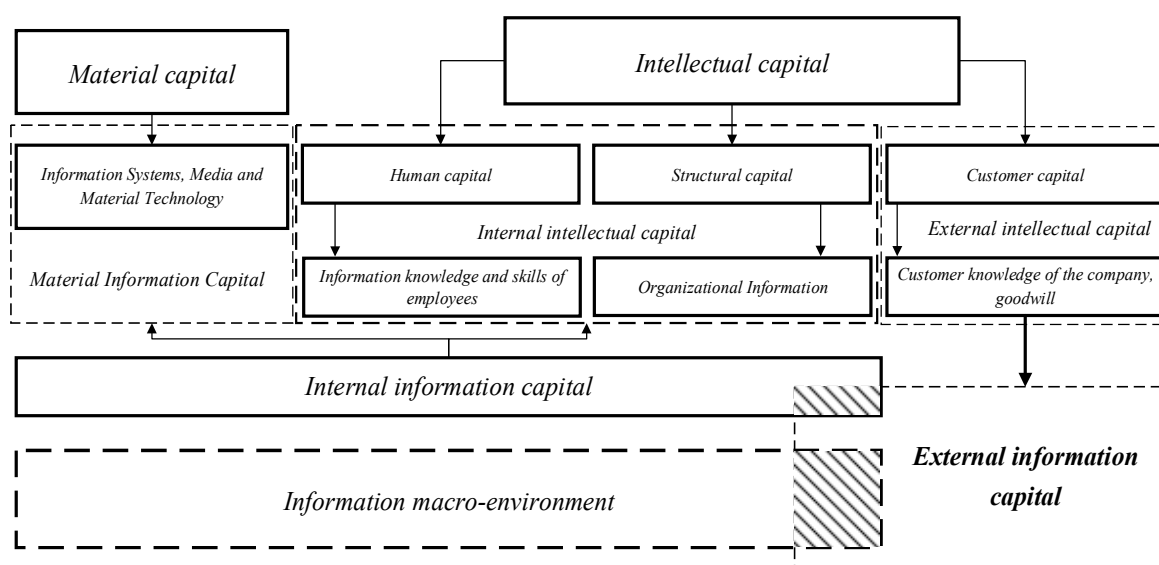


Figure 1. Information capital in the generalized structure of intellectual capital. Source: developed by the authors.

The study of information capital should be conducted in terms of the classical properties of capital: liquidity and accumulation. This means that information capital can be accumulated and reproduced in the process of economic turnover, and it should be easy to transform it into financial resources.

External information capital is important for the enterprise as it contributes to the development of user relationships outside the enterprise, which can increase the demand and lead to a long-term increase in revenues. Capital of this type not only activates demand and increases financial income, but also facilitates the growth of social, cultural, and political values.

3. Research Methodology

Mathematical methods in economics can be used not only to conduct a qualitative and quantitative assessment of individual values but also to find ways to manage them in order to achieve the greatest efficiency [40]. The evaluation of such a complex value as information capital cannot be made on the basis of classical valuation methods. First of all, this is due to the need to use both statistical and expert indicators characterizing the level of individual elements of information capital. There is also the need to identify fuzzy intervals of assessment and to take into account the level of expert confidence in the conclusions made. Therefore, one of the most suitable approaches to building a model for assessing information capital is a fuzzy-plural approach. Methods based on the theory of fuzzy sets are based on a system of multiple estimates, which, unlike statistical and expert

methods of estimation, make it possible to take into account the level of uncertainty by using membership functions ($\mu(x) \in [0; 1]$) [41–44].

Nedosekin was the first to have applied the theory of fuzzy sets to describe economic processes [45], the author proposes an algorithm for assessing a comprehensive economic indicator using the theory of fuzzy sets. The use of a fuzzy-multiple approach in economics is currently quite widespread. In particular, in the research of A.O. Nedosekin, this approach is applied to the assessment of financial risks, as well as to forecasting the production results of the enterprise [45]. The universality of this approach allows it to be applied to assess complex parameters of projects [45,46]. One of the few disadvantages of this approach is the need for the simultaneous use of both expert and statistical parameters, which significantly increases the complexity of practical use [47]. Based on this universal algorithm, many effective assessment models have been designed.

The algorithm for building fuzzy-multiple estimation models is shown in Figure 2.

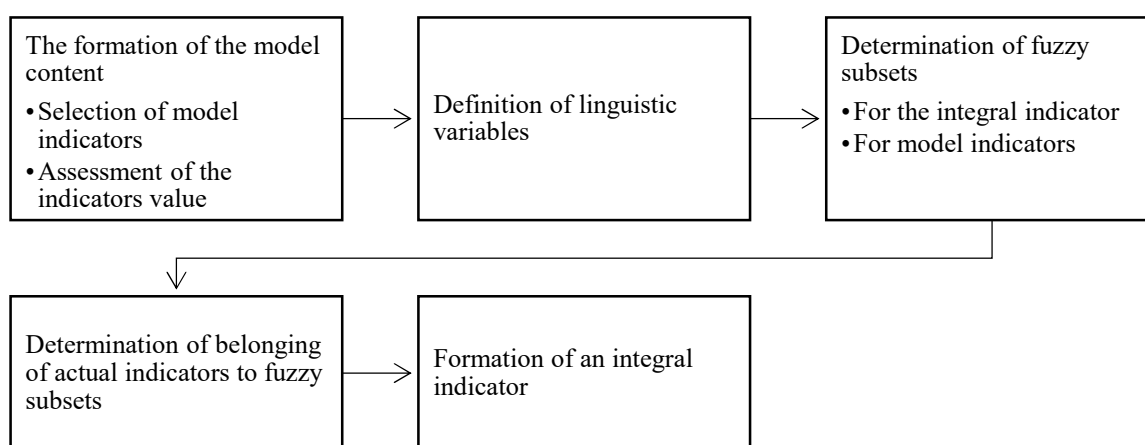


Figure 2. General algorithm for building fuzzy-multiple estimation models. Source: developed by the authors.

The use of this algorithm allows us to determine the areas for ensuring the sustainability of an industrial enterprise depending on external factors [45]. In this paper, we refer to an external information field as the external factor.

Information capital is a synergetic complex object, which determines the need to establish laws of interaction between its indicators. The mathematical description of this interaction does not consider the influence of the external environment. The interaction of the information capital elements produces many unstable trajectories that may be chaotic [48,49]. Consequently, a system of differential equations will be an effective description tool in this case.

External information capital is a complex and controversial category. Despite many attempts to study this phenomenon, a model for obtaining a qualitative assessment of the impact of the information field on the enterprise has not been built so far. The description of the interaction laws of the individual elements of external information capital in the external environment makes it possible not only to evaluate them but also to develop a model for external information capital management.

The methodology of this study presupposed a consistent differentiation of the information environment of an enterprise into a set of constituent elements. A quantitative assessment of these elements allowed a comparison of the enterprise both instantly with its competitors and dynamically with its own state in the past. Since the information environment of an enterprise is formed primarily from natural information, semantic analysis tools became the main tools of the methodology. The estimated resulting parameters of the information environment, in turn, cannot be interdependent, which is also subject to research at the meta-level. Thus, the methodology for conducting this study can be differentiated into three main stages—differentiation of the enterprise information environment, shaping the tools for assessing the selected elements of the enterprise information

environment on the basis of semantic analysis tools, and analyzing the mutual influence of the formed indicators.

4. Results

As mentioned above, the subject of this research is the external information capital of the enterprise. The external information capital of the enterprise should be understood as the relative value characterizing the perception of the enterprise by the subjects of the external environment [50]. This perception is multidimensional; in the framework of market relations, external information capital can be quantified in terms of demand for goods and services of the enterprise and of its competitors; in the framework of relations between business partners and investors, it can be expressed in terms of investment and future planning; and in the framework of relations between the enterprise and the state, this perception can be expressed in the number of tax and other inspections. We should focus on the fact that this value is relative and should be measured by means of a ranking scale. Essentially, this value reflects the strength and vector of influence of information environment on the relationship between the enterprise and the subjects of the external environment, which include actual and potential consumers, competitor enterprises, complementary enterprises, agents of the information environment (media, bloggers, and other opinion leaders) and representatives of the state (tax authorities, customs authorities, etc.). In the methodology section, two main objectives of this study were determined. First of all, let us consider the development of a fuzzy-plural model for assessing the index of external information capital. In accordance with the algorithm of Nedosekin, the primary stage of development is the identification of factors that influence the complex indicator under study. It is suggested that the index of external information capital is composed of the three basic components:

(1) The index of directed perception of the enterprise (I_d). This index reflects the general average perception of the enterprise by the subjects of the external environment and forms vector capital. Despite the general abstractness, this index also reflects the impact of the enterprise on the information environment. The fluctuations of this index result from the multidirectional activity of the enterprise itself and the presentation quality of this activity in the digital environment. The directed perception of the enterprise is fractal and can be controlled by the information pulses from the enterprise. These pulses can be characterized by two basic parameters—the directed force of influence (F_i) and frequency (T_i). These parameters are determined by the expert and measured in arbitrary points. It is suggested to introduce a ranking scale from 1 to 10. For strength, a value of 5 points is interpreted as the most neutral influence, while 1 point is the most negative influence, and 10 is the most positive influence. An increase in the frequency parameter is characterized by a constant increase from 1 to 10. However, the fractal nature of this parameter determines the nonlinearity of the distribution of the parameter's influence on the resulting index of the directed perception of the enterprise. Consequently, the nature of the influence of frequency on the directed perception of the enterprise is exponential. Thus, the directed perception of the enterprise can be defined as follows:

$$I_d = F_i \times e^{T_i} \quad (1)$$

Thus, the index of directed perception of the enterprise (I_d) is measured on a scale from 2.72 to 23,152.47.

(2) The tonality index of the information environment (I_t). This index reflects the tonality of the information background. The mechanism of influence of this indicator implies that the external information capital of the enterprise can be described through the transformation of consumer behavior due to changes in the tonality of the information environment. The level of inflation can be used as a basic indicator of consumer behavior transformation. Researchers mention many possible causes of rising inflation, but the key one is the increased aggregate demand. In our opinion, the aggregate demand in a stable economy can fluctuate due to the changes in inflation expectations and due to the changes

in the tonality of the information environment. Inflation expectations are a consequence of observing inflation fluctuations of the past period, thus, they can be represented in the form of an autoregressive variable. The tonality of the information environment can be expressed as a set of indicators. In this case, to assess the tonality of the information environment, we used the Dostoevsky library, an open library for semantic analysis using python. This library was formed on the basis of the RuSentimentdataset database and its accuracy in accordance with the F1 criterion is 0.71, which is a necessary and sufficient level of accuracy [51]. The analytic array was formed on the basis of news headlines and news annotations, the sources of which were: MK: News of Russia and the World (<https://www.mk.ru/news/> accessed on 20 June 2021), RIA Novosti (<https://ria.ru/> accessed on 20 June 2021), and Yandex.News (<https://yandex.ru/news> accessed on 20 June 2021). This choice is due to the fact that these news portals are the most popular in the Russian segment of the Internet, as evidenced by the traffic rating, and they are focused on the news content. The procedure for parsing information and creating a data frame involves collecting a daily array of news headlines and news annotations from all three resources, from 1 January 2016 to 1 February 2020, and subsequent aggregation of data into monthly arrays, which resulted in an array consisting of 49 observations. The Dostoevsky library allows you to obtain the characteristics of a text array from the analysis of the Negative and Positive tonality, the ratio of which allows you to create many possible regressors. Based on the analysis results, the following regression model was obtained:

$$I_n = 0.89 + 0.95 \times I_{n-1} - 0.09 \times \left(\frac{Negative_{n-1}}{Positive_{n-1}} \right)^2 \quad (2)$$

1. I_n is the inflation rate for the month n ;
2. I_{n-1} is the inflation rate for the month $n - 1$ (autoregressive component, reflecting the level of inflation expectations);
3. $Negative_{n-1}$ is the level of negative tonality of the information environment for the month $n - 1$;
4. $Positive_{n-1}$ is the level of positive tonality of the information environment for the month $n - 1$.

The normalized R^2 of this equation was 0.96, which indicates an extremely high-quality model. The standard error is about 6% and the p -level of each of the regressors does not exceed 0.05. Figure 3 shows a graphical interpretation of the results of this model.

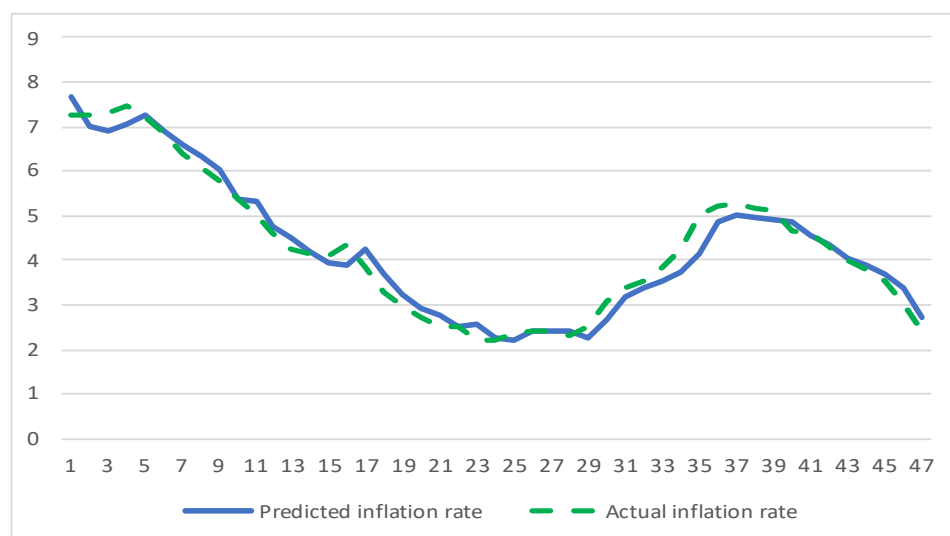


Figure 3. Dynamics of the actual and predicted inflation rate. Source: developed by the authors.

As can be seen in the graph, there are no significant structural gaps and outliers, which indicates a high-quality approximation. The form of the regressor reflecting the influence of the tonality of the information environment is determined empirically (the decreasing p-level was the selection criterion), hence it can be argued that, in terms of influencing the external information capital of the enterprise, the tonality of the information environment is determined by the square of the ratio of the negative and positive tonal component. At the same time, the impact of this index on inflation is negative. This fact fully confirms the hypothesis that, with an increase in the negative tonal component, an individual tends to reduce his level of consumption and increase his savings. The influence of this index on the index of external information capital can be considered as reciprocal. Therefore, the tonality index of the information environment (I_t) is calculated as follows:

$$I_t = -\left(\frac{\text{Negative}}{\text{Positive}}\right)^2 \quad (3)$$

(3) The sustainability index of the information environment (I_s). This index reflects the volatility of the content component of the information environment. At a high level of this indicator, the information environment can be characterized as unstable. The content component of the information environment can be characterized by a cloud of tokens and the frequency of mentioning a particular token. The emergence of new tokens may indicate the transformation of the content component of the information environment, and their share reflects its volatility. This indicator can be defined as follows:

$$V = \frac{\sum_1^i \text{new}.F_{t_n}}{\sum_1^j F_{t_{n-1}}} \quad (4)$$

1. V is the indicator of the transformation of the content component of the information environment;
2. $F_{t_{n-1}}$ is the frequency of the token in the period $n - 1$;
3. $\text{new}.F_{t_{n-1}}$ is the frequency of the emergence of a new token in the period n ;
4. i is the number of new tokens in the period n ;
5. j is the total number of tokens in the period $n - 1$.

It is suggested to use lemmatized word forms typical for the information environment as tokens. For these purposes, an open library in python, NLTK, can be used effectively.

So, these factors fully characterize the influence of the information environment on the external information capital of the enterprise and form a fuzzy-multiple model for assessing this value. This model highlights one integral linguistic variable—the Index of External Information Capital (E.I.C.I.). It was decided not to differentiate the basic terminology set into subsets. However, this integral indicator is the resulting indicator of the model. For each private indicator, a linguistic variable has been formed, such as the value of the private indicator. The basic term set in the case of these indicators has five subsets:

- (1) Invalid indicator value;
- (2) The low value of the indicator;
- (3) The average value of the indicator;
- (4) The high value of the indicator;
- (5) The indicative value of the indicator.

A standard five-level 01-classifier is selected as a classifier for particular indicators. This choice is due to the ability to universalize the assessment of the studied parameters by means of five comparative states. In the classifier, a segment of the material axis is a carrier of a linguistic variable $[0; 1]$ (01-carrier). Thus, each of the segments essentially corresponds to one or another comparative state of the parameter under study. In order to describe the type of these subsets, a system of five membership functions is introduced

that characterize the degree of belonging of a segment of 01-carrier values to a given subset (Table 1).

Table 1. T-numbers {y} for the values of a linguistic variable.

Subset	Indicator		
	Id	It	Is
Invalid value of the indicator	(2.71; 2.72; 2574.91; 5147.11)	(−81; −81; −70.9; −60.8)	(0; 0; 0.1; 0.2)
Low value of the indicator	(2574.91; 5147.11; 7719.30; 10291.50)	(−70.9; −60.8; −50.6; −40.5)	(0.1; 0.2; 0.3; 0.4)
Average value of the indicator	(7719.30; 10291.50; 12863.69; 15435.89)	(−50.6; −40.5; −30.4; −20.6)	(0.3; 0.4; 0.5; 0.6)
High value of the indicator	(12863.69; 15435.89; 18008.08; 20580.28)	(−30.4; −20.6; −10.1; −0.01)	(0.5; 0.6; 0.7; 0.8)
Indicative value of the indicator	(18008.08; 20580.28; 23152.47; 23152.47)	(−10.1; −0.01; −0.01; −0.01)	(0.7; 0.8; 0.8; 0.8)

Source: developed by the authors.

The values in the table correspond to the values of the indicators characterizing them from the point of view of their comparative state. The distribution of the specific gravity of the influence of the used indicators is extremely uneven. This is due to the fact that the index of directed perception of the enterprise (I_d) has a significantly greater impact on the integral indicator. At the same time, the specific weight of the influence of other indicators is comparable, which results in the following distribution: $r\{I_d; I_t; I_s\} = \{0.6; 0.2; 0.2\}$. This distribution of the specific weight of the influence of indicators was determined by experts and requires clarification.

The given classifiers can be represented in the form of trapezoidal membership functions, where the membership functions (from 0 to 1) are on the ordinate axis and the terms are on the abscissa axis. The upper base of the trapezoid corresponds to the absolute confidence of the expert in the classification reliability, and the lower base corresponds to the belief that other values of the interval (0; 1) do not fall into the selected fuzzy subset. The lateral sides of the trapezoid reflect the fluctuation of the expert's opinion on the belonging of a particular segment on the 01-carrier to a certain term. There are five nodal points: $\{0.1; 0.3; 0.5; 0.7; 0.9\}$. These values allow the quantification of the level of membership of specific values of indicators to one or another subset. According to the calculation results of each of the particular indicators, their values are recognized by the criterion λ_{ij} [0; 1]. This indicator correlates the values of particular indicators with the values of the 01 carriers:

$$\lambda_{ij} = 1 - \frac{X_i - a_3^*}{a_4^* - a_3^*} \quad (5)$$

a_3^* and a_4^* are the T-numbers of the i -th subset of the term set.

Based on the results of recognition of the private indicator values, the integrated indicators are calculated:

$$E.I.C.I. = \sum_{i=1}^3 \sum_{j=1}^5 p_j \times r_i \times \lambda_{ij} \quad (6)$$

p_j are the nodal points of the 01 carriers:

$$p_j = 0.9 - 0.2 \times (j - 1) \quad (7)$$

j —is the number of subsets of the base term of the set.

This fuzzy-plural model allows us to estimate the index of external information capital in the range from 0 to 1. However, this model examines the isolated effect of these indicators on the external information capital of an enterprise, though they can influence each other. In a stable environment, the interaction of these indicators can be considered a closed system. Changes in each of the given parameters are autoregressive. Therefore, a change in each of them will depend on its past value, adjusted for the sensitivity

of the corresponding parameter to changes. The increment of other parameters has a positive effect on the directed perception of the enterprise. However, their cumulative effect should be adjusted taking into account the previously determined specific gravity. The tonality of the information environment is also increased by the increment of the remaining parameters. However, the adjustment of the specific gravity of the influence is not required in this case. On the contrary, the stability of the information environment decreases with the increment of the remaining indicators. Thus, the mutual influence of these indicators (in a standardized form) can be represented in the form of the following system of differential equations:

$$\begin{cases} \frac{dl_{st}}{dt} = \alpha \times l_s - l_t \times l_d \\ \frac{dl_{it}}{dt} = \beta \times l_t + l_s \times l_d \\ \frac{dl_{dt}}{dt} = d \times l_d + \frac{l_s \times l_t}{3} \end{cases} \quad (8)$$

- (1) α is the coefficient of sensitivity of the stability index of the information environment (l_s) to its changes in the past period;
- (2) β is the coefficient of sensitivity of the tonality index of the information environment (l_t) to its changes in the past period;
- (3) d is the coefficient of sensitivity of the directed perception index of the enterprise to its changes in the past period.

So, this system of differential equations has the form of The Chen-Lee attractor, which allows us to draw many unstable trajectories with a chaotic character [6]. This system is characterized by dynamic chaos. Let us give an example for a linear change in the values of t from 0 to 100, which forms 40,000 observations. With the basic values of the indicators l_d , l_t and l_s equal to 1, 1, and 1, respectively, and the basic values of the coefficients α , β , and d equal to 5, -10 , and -0.38 , this attractor will take the following form (Figure 4).

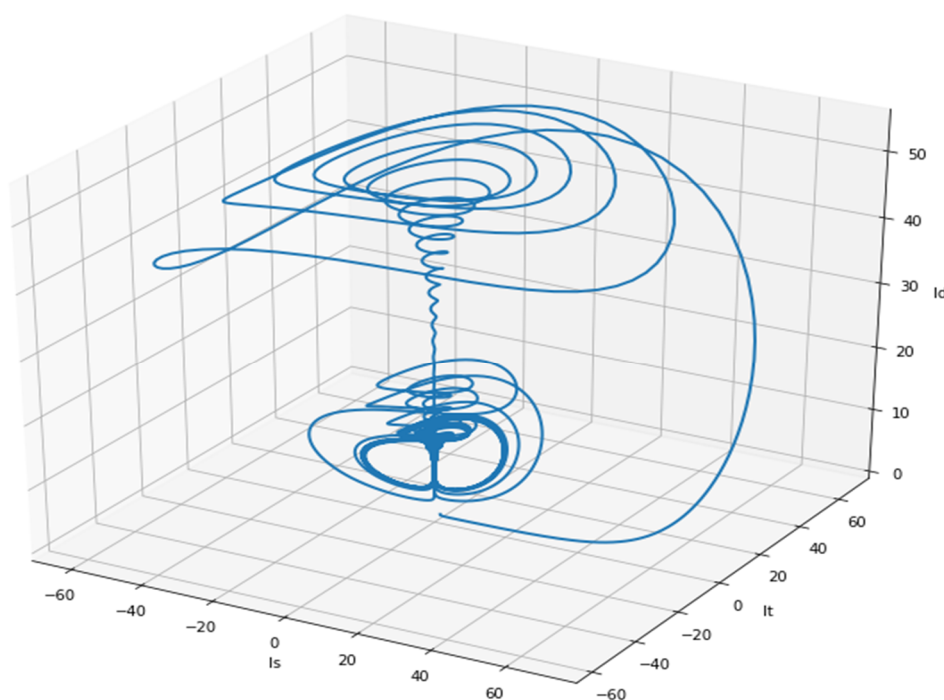


Figure 4. Change in the target parameters of the system at the basic values of the parameters of the Chen–Lee attractor. Source: finalized by the authors.

It can be concluded that the tonality and stability of the information environment have heterogeneous dynamics. They fluctuate harmoniously with a change in the directed

perception of the enterprise. The area of relative rest characterizes the stable increment of the positive information flow related to the enterprise. Deviations in the increment of this stream provoke changes and, consequently, chaotic fluctuations in the tonality and stability of the information environment. Therefore, a significant increase in the directed information flow from the enterprise or its abrupt termination can provoke chaotic changes in the information environment, and lead to unpredictable results.

5. Discussion

In accordance with the results obtained, we can state that the external information capital of the enterprise is a multidimensional partially manageable category. The theses of some researchers about the connection of external information capital and its business reputation are only partially true, primarily because business reputation is formed solely as a result of the actions of the enterprise. The volatility of external information capital is ensured both by the actions of the enterprise and the state of the information environment. Figure 5 shows the process of the development of external information capital.

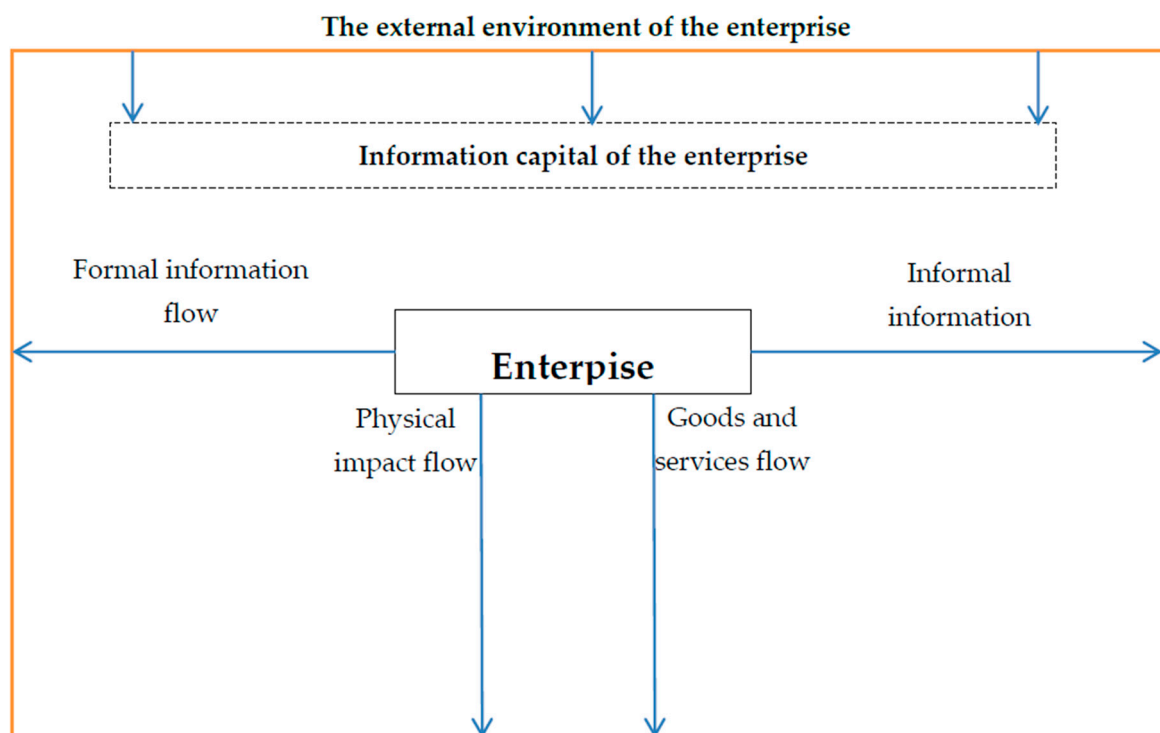


Figure 5. The process of development of information capital. Source: developed by the authors.

As can be seen in Figure 4, information capital is formed outside the enterprise, under the influence of the external environment. The enterprise generates the information flow that enters the external environment. This stream contains both formal information (sales statistics, company mission, press releases of company management, accounting data, etc.) and informal information (reviews of employees and managers, employee pages on social networks, etc.). This aggregate information flow is quite heterogeneous and is differentiated depending on the target audience. Besides the information flow, the enterprise also produces the flow of goods and services, which contributes to the main perception of the enterprise by actual consumers. The company also generates an outgoing flow of physical impact. This impact can be divided into social, environmental, political, and scientific, and technological impacts. The content of these flows, getting into the external environment, begins to actively interact with the content of flows from other enterprises, and with the number of entities of the external environment. This interaction develops the external information capital of the enterprise.

Flows from the enterprise can be synchronized with the external environment, which will ensure the relative stability of information capital. However, the stability and tonality of the information environment are rarely in a stable state. A large FMCG market enterprise with a relatively constant Id ranging from 7 to 8 points can be given as an example. Let us consider a hypothetical situation in which the company has a stable level of Id at 7.5 points. The It and Is indicators are determined in accordance with the methodology described earlier using the data obtained in the framework of the analysis of inflationary fluctuations. The dynamics of the intermediate indicators, as well as the integral indicator, are shown in Figure 6.

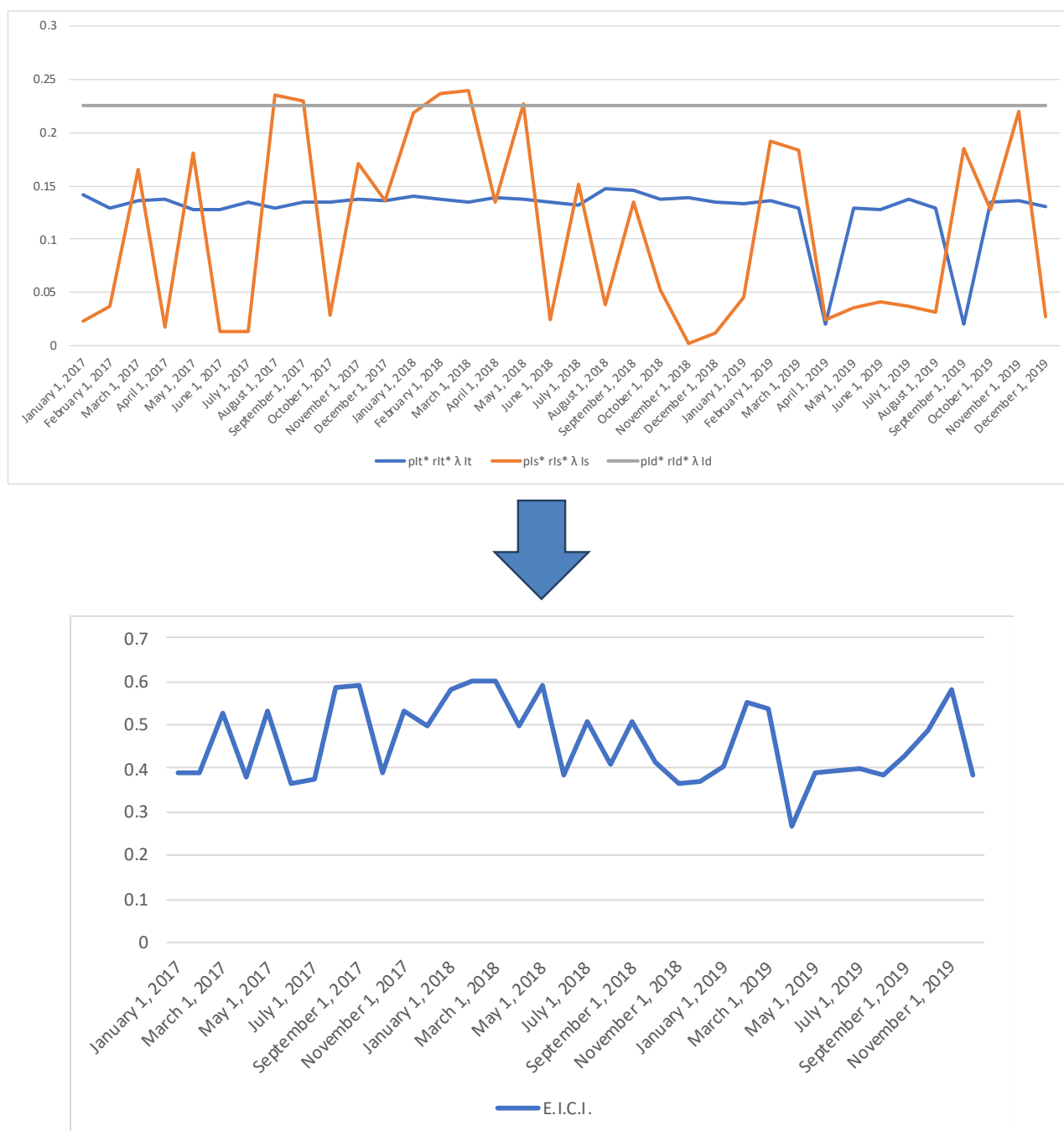


Figure 6. Dynamics of the external information capital index of a hypothetically stable FMCG market enterprise in 2017–2019. Source: developed by the authors.

The graph shows that, despite the constant value of the index of directed perception of the enterprise (I_d) and the relatively constant value of the index of stability of the information environment, significant fluctuations in the tonality index of the information environment (I_t) caused the volatility of the external information capital index. Thus, we can conclude that even with a stable directed perception of the enterprise, the external information capital of the enterprise can fluctuate due to the fact that it is developed outside the enterprise.

6. Conclusions

This study has introduced a new concept—external information capital that characterizes the perception of the enterprise by the subjects of the external environment. This parameter is developed outside the enterprise as a result of the enterprise mediation in the information environment, and it reflects the state of the information environment in terms of its stability and tonality. The dynamics of external information capital is extremely important for the enterprise since it reflects the perception of the enterprise by its consumers, competitors, contractors, and other agents of the external environment, especially in the conditions of the digital economy. In the digital economy, the speed of exchange and the accessibility of information has significantly enhanced the impact of this indicator on the company's economic results. The systemic fluctuations of this indicator were described using the Chen–Lee attractor model, with the following elements: the stability index of the information environment (I_s), the index of tonality of the information environment, and the index of directed perception of the enterprise (I_d) as proposed by the authors. This model allows us to find out that the tonality and stability of the information environment fluctuate harmoniously with the changes in the directed perception of the enterprise, and there is also an area of relative rest, which characterizes the stable increment of the positive information flow related to the enterprise. Thus, significant fluctuations in the directed information flow from the enterprise can provoke chaotic changes in the information environment, and, as a result, lead to unpredictable results. To model these changes, the authors developed a model for evaluating the index of external information capital (E.I.C.I), based on a fuzzy-multiple approach, which involves the stability index of the information environment (I_s), the tonality index of the information environment (I_t), and the index of directed perception of the enterprise. This model allows us to assess the state of the external information capital of the enterprise and simulate its change as a result of various kinds of information-resonance events (for example, marketing campaigns). Approbation of the developed model made it possible to establish its potential effectiveness. Analysis of changes in the model indicators allows an enterprise to formulate a development strategy in the information environment, or a strategy to compensate for the consequences of information impact from competitors. Also, this model can be used in the framework of competitive analysis to identify the most effective moment of impact on competitors. This model can be used by consumers to compare possible alternatives, as well as to shape consumer preferences. However, the multitasking of the developed model is combined with its conditional universality. Consequently, the model will require refinements for use within specific sectors of the economy. The considered example clearly demonstrates the need to take into account the specifics of the industry or the market. In the framework of subsequent studies, it is assumed that this model will be specified for individual sectors of the economy and its efficiency will be assessed. It can be concluded that this model is of high practical importance, and it can be used by specialists in the field of marketing and branding, companies planning large-scale information transformations, as well as researchers in the field of information.

Author Contributions: All the authors have contributed substantially to the entire work reported. All authors have read and approved the final manuscript. Conceptualization, D.R. and A.Z.; methodology, E.K., Y.D., and N.D.; writing—drafting, D.R.; writing—inputs, all authors; writing—reviewing and editing, all authors. All authors have read and agreed to the published version of the manuscript.

Funding: The study was supported by the Academic Excellence Project 5-100 proposed by Peter the Great St. Petersburg Polytechnic University.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Data available in a publicly accessible repository.

Acknowledgments: The research was supported by the Peter the Great St. Petersburg Polytechnic University.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Zaytsev, A.; Rodionov, D.; Dmitriev, N.; Kichigin, O. Comparative analysis of results on application of methods of intellectual capital valuation. In Proceedings of the International Scientific Conference, Digital Transformation on Manufacturing, Infrastructure and Service, St. Petersburg, Russian, 21–22 November 2019.
2. Zaytsev, A.; Dmitriev, N.; Talerchik, S. Intellectual Rent as A Necessary Element in The Transition to Noonomics. In Proceedings of the 35th IBIMA Conference, Seville, Spain, 1–2 April 2020.
3. Drucker, P. *Post-Capitalist Society*, 1st ed.; Butterworth-Heinemann: Oxford, UK, 1993.
4. Drucker, P. *Technology, Management and Society*; Taylor and Francis: London, UK, 2012.
5. Constantinescu, E.; Ciobota, G. Globalization and restructuring in the information society. *Qual. Access Success* **2013**, *14*, 514–519.
6. Chen, H.K.; Lee, C.I. Anti-control of chaos in rigid body motion. *Chaos Solitons Fractals* **2004**, *21*, 957–965. [\[CrossRef\]](#)
7. Odero, K. Information capital: 6th asset of sustainable livelihood framework. *Discov. Innov.* **2006**, *18*, 83–91. [\[CrossRef\]](#)
8. Asaturova, Y.; Khvatova, T. How constraints influence company innovation processes. In Proceedings of the European Conference on Innovation and Entrepreneurship, Kalamata, Greece, 19–20 September 2019; Volume 1, pp. 95–103.
9. Nikolova, L.V.; Malinin, A.M.; Rodionov, D.G.; Velikova, M.D. Performance management of innovation program at an industrial enterprise: An optimisation model. In Proceedings of the 30th IBIMA Conference, Madrid, Spain, 8–9 November 2017; Volume 2017, pp. 1033–1040.
10. Jahanian, R.; Salehi, R. Managing Intellectual Capital in Organizations. *Int. J. Hum. Resour. Stud.* **2013**, *3*, 121. [\[CrossRef\]](#)
11. Masuda, Y. *The Information Society as Post-Industrial Society*; World Future Society: Washington, DC, USA, 1981.
12. Martin, W.J. *The Global Information Society*; Aslieb Gower: Aldershot, UK, 1995.
13. Castells, M. *The Information Age: Economy, Society and Culture*; Blackwell Publishers: Oxford, UK, 1996.
14. Kelly, K. *New Rules for the New Economy. Ten Radical Strategies for a Connected World*; Penguin Books: New York, NY, USA, 1998.
15. Webster, F. *Theories of the Information Society*, 2nd ed.; Routledge: London, UK, 2002.
16. Zeinali, K.; Zadeh, F.; Hosseini, S. Evaluation of the impact of information technology capital and intellectual capital on future returns of companies in the capital market. *Int. J. Learn. Intellect. Cap.* **2019**, *16*, 239–253. [\[CrossRef\]](#)
17. Roy, D. Intellectual property strategy for competitive advantage. *Int. J. Intellect. Prop. Manag.* **2013**, *6*, 36–61. [\[CrossRef\]](#)
18. Nath, H.K. The information society. *Space Cult. India* **2017**, *4*, 19–28. [\[CrossRef\]](#)
19. Mueller, M.; Grindal, K. Data flows and the digital economy: Information as a mobile factor of production. *Digit. Policy Regul. Gov.* **2019**, *21*, 71–87. [\[CrossRef\]](#)
20. Bharadwaj, A. A resource-based perspective on information technology capability and firm performance: An empirical investigation. *MIS Q.* **2000**, *24*, 169–196. [\[CrossRef\]](#)
21. Silkina, G. From analogue to digital tools of business control: Succession and transformation. *IOP Conf. Ser. Mater. Sci. Eng.* **2019**, *497*, 012018. [\[CrossRef\]](#)
22. Leventsov, V.; Radaev, A.; Nikolaevskiy, N. *Design Issues of Information and Communication Systems for New Generation Industrial Enterprises*; Springer: New York, NY, USA, 2017; Volume 10531, ISBN 9783319673790.
23. Anisiforov, A.B.; Dubgorn, A.S. Organization of enterprise architecture information monitoring. In Proceedings of the 29th IBIMA Conference, Vienna, Austria, 3–4 May 2017; pp. 2920–2930.
24. Ziemba, E. The Contribution of ICT Adoption to the Sustainable Information Society. *J. Comput. Inf. Syst.* **2019**, *59*, 116–126. [\[CrossRef\]](#)
25. Cawsey, T.; Rowley, J. Social media brand building strategies in B2B companies. *Mark. Intell. Plan.* **2016**, *34*, 754–776. [\[CrossRef\]](#)
26. Albersmann, W.; Quick, R.; Walle, E. Information content of goodwill impairments. *Betr. Forsch. Prax.* **2017**. [\[CrossRef\]](#)
27. Nguyen, P.; Kecskes, A. Do technology spillovers affect the corporate information environment? *J. Corp. Financ.* **2020**, *62*. [\[CrossRef\]](#)
28. Demidenko, D.S.; Kulibanova, V.V.; Maruta, V.G. Using the principles of “digital economy” in assessing the company’s capitalization. In Proceedings of the 31st IBIMA Conference, Milan, Italy, 25–26 April 2018; pp. 6087–6091.
29. Jordao, R.; Novas, J.; Gupta, V. The role of knowledge-based networks in the intellectual capital and organizational performance of small and medium-sized enterprises. *Kybernetes* **2019**, *40*, 116–140. [\[CrossRef\]](#)

30. Gertrudis-Casado, M.; Gertrudix-Barrio, M.; Alvarez-Garcia, S. Professional information skills and open data. Challenges for citizen empowerment and social change. *Comunicar* **2016**, *24*, 39–47. [\[CrossRef\]](#)
31. Shipunova, O.D.; Berezovskaya, I.P.; Mureyko, L.M.; Evseev, V.V.; Evseeva, L.I. Personal intellectual potential in the e-culture conditions. *Espacios* **2018**, *39*, 15.
32. Kalchenko, O.A.; Tikhomirov, A.F.; Evseeva, S.A. Sustainability-oriented innovative projects (experience of Russia and Saint-Petersburg). *Proc. Voronezh State Univ. Eng. Technol.* **2018**, *79*, 274–281. [\[CrossRef\]](#)
33. Dolzhenko, I.B. *Information Technologies and Changes in the External Environment of TNCs in the Consumer Sector // Economics and Business: Theory and Practice*; Capital LLC: Novosibirsk, Russia, 2019; pp. 39–43.
34. Randolph, R.V.; Hu, H.-F.; Silvernail, K.D. Silvernail, Better the devil you know: Inter-organizational information technology and network social capital in coopetition networks. *Inf. Manag.* **2020**, *57*, 103344. [\[CrossRef\]](#)
35. Hu, Y.-P.; Chang, I.-C.; Hsu, W.-Y. Mediating effects of business process for international trade industry on the relationship between information capital and company performance. *Int. J. Inf. Manag.* **2017**, *37*, 473–483. [\[CrossRef\]](#)
36. Rudskaya, I.; Ozhgikhin, I.; Kryzhko, D. Developing and Testing an Algorithm to Identify Future Innovative Research Areas in Digitalization Conditions (using a Medical-sector example). *Int. J. Technol.* **2020**, *11*, 1213–1222. [\[CrossRef\]](#)
37. Stewart, T.; Ruckdeschel, C. Intellectual capital: The new wealth of organizations. *Perform. Improv.* **1998**, *37*, 56–59. [\[CrossRef\]](#)
38. Jarvis, P. *Globalisation, Lifelong Learning and the Learning Society*; Routledge: New York, NY, USA, 2007; Volume 2.
39. Vetrenko, P.P.; Chernysheva, E.A.; Levitina, I.Y.; Voronkova, O.V.; Mikheeva, D.G. Encouraging Employees to Increase the Labor Intellectualization Level as a Factor of Evolution of the Intellectual Capital. *Eur. Res. Stud. J.* **2017**, *20*, 568–577.
40. Degtereva, V.; Zaytsev, A.; Kichigin, O.; Dmitriev, N. Application of the Game-Theoretic Method in the Development of an Investment Behavior Strategy. In Proceedings of the 34th IBIMA Conference, Madrid, Spain, 13–14 November 2019.
41. Rodionov, D.G.; Konnikov, E.A.; Konnikova, O.A. Approaches to ensuring the sustainability of industrial enterprises of different technological levels. *J. Soc. Sci. Res.* **2018**, *S3*, 277–282.
42. Beilin, I.L. Fuzzy modeling economic risk of innovative chemical project. *Int. J. Econ. Perspect.* **2017**, *11*, 339–345.
43. Hao, Z.; Xu, Z.; Zhao, H.; Su, Z. Probabilistic dual hesitant fuzzy set and its application in risk evaluation. *Knowl. Based Syst.* **2017**, *127*, 16–28. [\[CrossRef\]](#)
44. Yager, R. Uncertainty modeling using fuzzy measures. *Knowl. Based Syst.* **2016**, *92*, 1–8. [\[CrossRef\]](#)
45. Nedosekin, A.O.; Reischahrit, E.I.; Ilyenko, E.P. Fuzzy model of motivation based on industrial safety factor. In Proceedings of the 2016 XIX IEEE International Conference on Soft Computing and Measurements (SCM), St. Petersburg, Russia, 25–27 May 2016; pp. 386–387. [\[CrossRef\]](#)
46. Kozlovsky, A.N.; Nedosekin, A.O.; Kokorin, M.S. Fuzzy Model for Estimation and Prediction of Stock Market System. In Proceedings of the 23rd International Conference on Soft Computing and Measurements, SCM 2020, St. Petersburg, Russia, 27–29 May 2020; pp. 86–87.
47. Abdoulaeva, Z.I.; Nedosekin, A.O. Mobilized economy fuzzy model. In Proceedings of the International Conference on Soft Computing and Measurements, SCM 2015, St. Petersburg, Russia, 19–21 May 2015; pp. 267–268.
48. Lozi, R.; Pchelintsev, A. A new reliable numerical method for computing chaotic solutions of dynamical systems: The Chen attractor case. *Int. J. Bifurc. Chaos* **2015**, *25*, 1550187. [\[CrossRef\]](#)
49. Lu, J.; Zhou, T.; Chen, G.; Zhang, S. The compound structure of Chen's attractor. *Int. J. Bifurcat. Chaos* **2002**, *12*, 855–858. [\[CrossRef\]](#)
50. Rodionov, D.G.; Konnikov, E.A.; Alferev, D.A. Information capital of an enterprise as a target indicator of development in the framework of digital economic systems. *Econ. Sci.* **2020**, 131–137. (In Russian) [\[CrossRef\]](#)
51. Rogers, A.; Romanov, A.; Rumshisky, A.; Volkova, S.; Gronas, M.; Gribov, A. RuSentiment: An Enriched Sentiment Analysis Dataset for Social Media in Russian. In Proceedings of the COLING 2018, Santa Fe, NM, USA, 21–24 August 2018.