Bilateral Economic Relations in the Era of Digitalization of the World Economy: Application of the Gravitational Approach

R V Naumenko[1], E S Nesterenko[1]

[1]V.I. Vernadsky Crimean Federal University, Republic of Crimea, Simferopol, 295009, RF

E-mail: cf_university@mail.ru

Abstract. The modern economy is characterized by significant changes in globalization and internationalization of the world economy. Global digitalization is becoming a General trend of economic development that determines the competitiveness of the state in the world economy. The authors present the characteristics of the digital economy at the present stage of development of the world economy. The theoretical substantiation of the gravitational bases of the digital economy is proposed, within the framework of which the gravitational equation with adjustments for global changes is developed. The peculiarities of bilateralism in the conditions of digitalization of the world economy are also revealed. The conclusion is made about the desire of developed digital powers to cooperate with countries of a similar digital level, and countries with a lower level of digitalization have a wider range of digital distances, which decreases as the level of development of the digital economy increases, which indicates the desire for economic growth in the conditions of the impossibility of abandoning The authors' developments fit into the conceptualization of the influence of geographical distance on the economic interaction of States.

1. Introduction

Currently, the world economy is characterized by significant changes that contradict the classical principles of globalization and internationalization of the world economy. Geo-economic and geopolitical crisis leads to a natural change of unipolar formation, which is the cause of artificial trade wars and a surge of complex protectionism. At the same time, the multilateral format of economic relations of countries, which provides for the settlement of such conflicts, has systemic imbalances, the key element of which is "cooperative power".

At the same time, global digitalization is already a General trend of economic development which determines the competitiveness of the state in the world economy. This process is characterized by the comprehensive introduction of information and communication technologies and end-to-end technologies, which leads to high-quality transformation processes in national economies, inter-state relations and plurilateral cooperation.

Under the circumstances, there is a change in the fundamental bases of foreign economic policy of the state, market aspects of which acquire new elements. This implies the need to revise the concepts of bilateral economic cooperation.

The purpose of this work is to identify the significance of the digitization of modern bilateral economic relations of the countries.

The study has the following structure. The first section presents the characteristics of the digital economy at the present stage of development of the world economy. The second section is devoted to the theoretical substantiation of gravitational bases of the digital economy, within which the gravitational equation with adjustments for global changes is developed. The third section presents the results of empirical testing of the gravitational equation. The fourth section reveals the peculiarities of bilateralism in the conditions of digitalization of the world economy.

2. Digital economy as an element of the world economy transformation

The digital economy is a system of economic relations based on the realization of digital human potential through the use of information and communication and end-to-end technologies, functioning in a sustainable innovation-oriented institutional environment aimed at increasing productivity and improving the welfare of society in the production, distribution, exchange and consumption of goods and services [1].

McKinsey estimates that one new job in the ICT sector stimulates the creation of 2-4 jobs in the economy as a whole. According to estimates from PWC, the growth of digitalization by 10% reduces the unemployment rate by 0.84% [2, p. 9]. In fact, the introduction of digital technologies and the development of the digital economy at the global level leads to the solution of global economic problems.

Of particular importance in the scale of digitalization of the world economy is the transformation of the modern foundations of economic activity, involving changes in the characteristics of production and consumption, and the creation of new industries and markets. Moreover, there is a formation of a new paradigm of the world economy, which allows to unite countries in the concept of civilization evolution, focused on quality growth [3, c. 20].

The main reasons for this process include:

1.High scientific and technologic direction of economic activity, providing for the formation of the hierarchy of the world economy, as a result of which the developed countries seek to maintain foreign economic domination, and the developing countries are aimed at changing their own status as a personnel donor and raw material appendage;

2.Global population growth coupled with the increasing economic gap between rich and poor;

3.Limited resources to meet socio-economic needs.

The development of the digital economy activates the processes of global economic transformation, which require taking into account modern technological trends, including [4]:

- big data.

The volume of world IPtrafic over the past three years increased 1.5 times which implies the empowerment process unstructured data, increased requirements to the standards for the collection, storage and processing of information, the stricter rules of data protection, the development of predictive Analytics.

-quantum technology.

It is expected to increase the power of computers which will solve specialized problems that require a high degree of reliability of calculations.

- robotics and sensors.

Currently, the average annual growth rate of the global robotics market is from 7 to 15 % depending on industries. This leads to increased productivity, minimizing the number of accidents at work, optimizing business processes and reducing energy costs.

-Neurotechnology and artificial intelligence.

The market of artificial intelligence over the past three years has grown more than 2.5 times. As a result, there is a new level of development of artificial intelligence, providing for a gradual restructuring of the world labour market and the emergence of new forms of legal relations between people and robots.

- new production technologies.

The volume of the market of smart technologies in the last five years has grown almost 1.5 times. As a result, the process of greening the world economy and increasing the level of customization of goods and services has been accelerated.

- Commerce and the Internet.

Development of M2M Technology providing for the creation of a new type of companies based on the integration of information and production processes [5].

- block chain.

The market of technologies of the distributed registry within the last three years has increased almost 1.5 times which allows to minimize the number of intermediaries in the business processes to simplify international transfers and to increase the security of transactions.

- wireless communication.

The development of this direction allows to minimize the costs of companies. This is aimed at reducing the role of the geographical factor in foreign economic activity and optimizing economic activity.

- virtual and augmented reality technologies.

The virtual reality market has almost tripled from 2016 to 2018. As a result, there is a development of virtual advertising, virtual education and social activity of pensioners and people with disabilities.

At the same time, the defining element of the world economy remains the person. Automated technological systems do not have the ability to make decisions in extraordinary situations. This implies the existence of the subject task definitions governing the operations of the mechanism. Consequently, technology is the result of the scientific activity of the individual and has the status of a tool that brings a person the opportunity to achieve certain goals. The effectiveness of the digital economy is determined by the achieved economic indicators, the success of which largely depends on the competence of the workforce.

Moreover, artificial intelligence can misinterpret certain events. It is the person who is the keeper of information which displays the experience of past generations. Reflection of the advanced thought and the collected knowledge assumes emergence of qualitatively new ecosystem allowing to make strategic decisions [6, page 19].

The digital economy should be subject to comprehensive control and regulation by the state, the basis of which will be the concept of digital management based on the principle of "connectivity" of the economic entities [7, p. 33]. The state through the system of national institutions forms a digital institutional environment that regulates the economic activity of economic entities.

At the same time, the state seeks to create a system that would ensure information security and economic independence of the country from internal and external threats. An integral element of these actions is the development of a favourable institutional environment that takes into account all five groups of institutions of the digital economy development: regulatory institutions, institutions of education, institutions of culture, institutions of science, institutions of employment [8, p. 26-30].

In addition, the current digital system puts forward new requirements to the participants of the labour market. This leads to an objective need for coordination at the state level of the process of mastering digital competencies by the workforce.

As a result, the modern digital transformation, being an integral part of global economic processes, affects the theoretical bases of foreign economic relations, providing for the need to take into account new indicators in the study of the conceptual foundations of the world economy.

3. Gravitational aspects of the digitalization of the world economy

3.1. Theoretical foundations of the gravity model

Assessment of changes in foreign economic activity in the process of global digitalization leads to the use of specific techniques that reflect these changes. These include the gravitational equation. In 1962, J. Tinbergen proposed a gravitational model of international trade. In his work the author was guided

by Newton's law of Universal gravitation arguing that trade relations between countries are directly proportional to the scale of the economy and inversely proportional to the distance between them[9]:

$$E_{ij} = a_0 Y_i^{a1} Y_j^{a2} D_{ij}^{a3} \quad (1)$$

X. Linneman took into account political and cultural elements in the analysis of trade determinants, which were expressed in terms of population size and existing preferences [10]. In his view, the gravitational model has the following form:

$$X_{ij} = B_0 Y_i^{B1} Y_j^{B2} N_i^{B3} N_j^{B4} D_{ij}^{B5} A_{ij}^{B6} P_{ij}^{B7} e \quad (2)$$

Later, G. Bergstrand forms the basic equation of international trade taking into account the plurality of indicators of the Anderson's gravitational model [11,12]:

$$PX_{ij} = B_0 Y_i^{B1} Y_j^{B2} D_{ij}^{B3} A_{ij}^{B4} u_{ij} \quad (3)$$

Where PX_{ij} is dollar flow from country i to country j, Y_i and Y_j – GNP in countries i and j, D – distance between countries i and j, A_{ij} - other factors influencing relations between countries, U_{ij} – probability of error [E(ln uij)=0].

A special position in the theory of gravity is occupied by the issues of heteroskedasticity (variability of error dispersion from one object to another) of data. In the empirical modeling of the processes of economic cooperation it was often used not a multiplicative form of the equation but logarithmically-linearized. The presence of inhomogeneous and zero values in the statistical series leads to the insolvency of the least squares method (hereinafter OLS) in the evaluation of coefficients [13]. J. Silva and S. Tenreiro solved this problem using the Poisson's method of maximum likelihood in the analysis of gravitational equations which allows to avoid heterogeneity of observations [14].

A. Shumilov emphasizes: "The Choice of a particular method depends crucially on the properties of the data under consideration (heteroskedasticity-homoscedasticity, large-small number of zero observations, etc.)" [13].

The gravitational equation allows to characterize the bilateral economic relations of the countries in a complex way, while not only standard indicators can be used as indicators of gravity, but also geographical features (common border, continent), trade agreements, exchange rate, consumer price index, national language, religion, etc. [15].

Focusing on the digitalization of the world economy, attention should be focused on the emergence of goods, the creation of which presupposes the existence of ICT. These include: communication equipment, consumer electronic equipment, computers, peripheral equipment, etc. In addition, computer, telecommunications and information services have been actively developed which is especially important in the context of the personification of a developed state with a high share of income from the services sector.

These changes affect a special review question of the gravitational theory of "death of distance" in the era of globalization. J. Melo, J. F. Brun, S. Carrere, P. Guilamont in their work "Has distance died: Evidence from a panel gravity model" on the basis of the gravitational equation taking into account the extended function of trade barriers analyzed this aspect. As a result, trade elasticity with respect to distance decreased by 11% between 1962 and 1996. At the same time, the authors note the fact that poor states are isolated from the globalization waves, while developed countries get the maximum benefits [16]. This is due to the process of formation of the ideology of technological development aimed at the realization of technological potential, expansion of the program of state innovation research and ensuring the continuous transfer of knowledge from the sphere of production to the sphere of consumption [17, p. 560].

The emergence and development of the digital economy has deepened these processes which is characterized by a change in the effect of distance in the foreign economic activity of the state. While the early export-oriented state was obliged to take into account the logistics aspect as one of the basic elements of the model of effective market functioning, today the developed services sector with the proper level of specialization allows to eliminate this element of market costs. Therefore, if the classical gravitational theory assumes closer economic interaction of nearby states (especially those with a

common border), then within the digital economy a special place is given to the distance in the levels of digitalization. We believe that the gravitational equation of bilateral economic relations in the conditions of digitalization of the world economy should have the following form:

$$lnT_{ij} = a_0 + a_1 lnY_i + a_2 lnY_j + a_3 \ln DigD_{ij} \quad (4)$$

where T_{ij} – trade turnover between countries i and j, Y_i и Y_j – GDP in countries i and j, $DigD_{ij}$ – digital distance between countries i and j, a_1, a_2, a_3 - elasticity coefficient.

We also assume that, given the multifactorial impact of the world economy, there is an objective need to take into account fictitious variables that have a direct impact on the digital economy. The common border will be not so geographical as psychological and historical context providing for ease of doing business with neighbouring countries. In addition, it is important to take into account the common language as an element of interpenetration of economies and integration interaction as an indicator of ease of doing business at the interstate level. The transformed equation 4:

$$lnT_{ij} = a_0 + a_1 lnY_i + a_2 lnY_j + a_3 \ln DigD_{ij} + a_4 lnCB + a_5 lnCL + a_6 lnIntegr \quad (5)$$

where CB – common boarder, CL – common language, a $Integr$ – integration cooperation.

3.2. Empirical results

It is necessary to specify the conditions of the calculations in advance:

1.The digital distance is calculated by the formula:

$$DigD_{ij} = |ICTInd_i - ICTInd_j| \quad (6)$$

The information and communication technology development Index (ICT DevelopmentIndex), calculated annually by the International telecommunication Union, was chosen as an indicator of the level of the digital economy.

2.The objects of the research are the four states with different levels of digitalization of the economy:

- Norway – 8,47 (8th place in the ranking);
- Russia – 7,07 (45th place in the ranking);
- Georgia – 5,79 (74th place in the ranking);
- India – 3.03 (134 place in the ranking).

3.The analysis is based on panel data for the period from 2012 to 2017 (2014 is excluded due to the inferiority of statistical information).

4.The least squares method was chosen as the calculation method.

5.The P-value is ≤ 15.

6.The databases of the Central Statistical Office of Norway, the Customs Service of Russia, the National Statistical Office of Georgia, the Ministry of Trade and Industry of India, the World Bank, the International Telecommunication Union and CEPII are used as sources of information.

Table 1. Results of calculations of the gravitational equation in the conditions of digitalization of the world economy (OLS).

	Norway	Russia	Georgia	India
const	-	−5513,57*	68498,0***	15693***
GDP 1	0,00787092***	0,00578417***	-	-
GDP 2	0,000802853***	0,00300046***	0,0343215***	0,02***
Dig D	−803,717***	-	−13942,1**	3691,59 **
CB	4003,21***	6567,38***	867418***	55145***
CL	-	13066,9***	-	-
Integr	-	-	-	-34511 **
R^2	0,36	0,33	0,65	0,57
0	440	320	445	415

Source: compiled by the authors on the basis of [18-24].

Note: P-value– 0,05 (***), 0,10 (**), 0,15 (*).

Construction of the model will be carried out using the software package of econometric research "Gretl".

Analyzing the results of the calculations, it should be noted that the probability of error in the rejection of the null hypothesis is extremely low. At the same time, the coefficient of determination has moderate values, which together with significant indicators of variables suggests the possibility of alternative outcomes. However, the calculations showed an inversely proportional relationship between the digital distance and the turnover, which fits into the provisions of the classical gravitational theory. The exception is India, the level of digitalization of which has quite low indicators, which changes the concept of foreign economic activity of the state. We estimate the level of heteroskedasticity of the digital distance (see Figure).

Fig. 1 shows a significant spread of data in the assessment of trade turnover of countries with a digital distance. The obtained results allow us to draw a conclusion about the need to take into account this feature and the use of generalized (weighted) least squares method under heteroskedasticity conditions which will reduce the variance in the calculations.

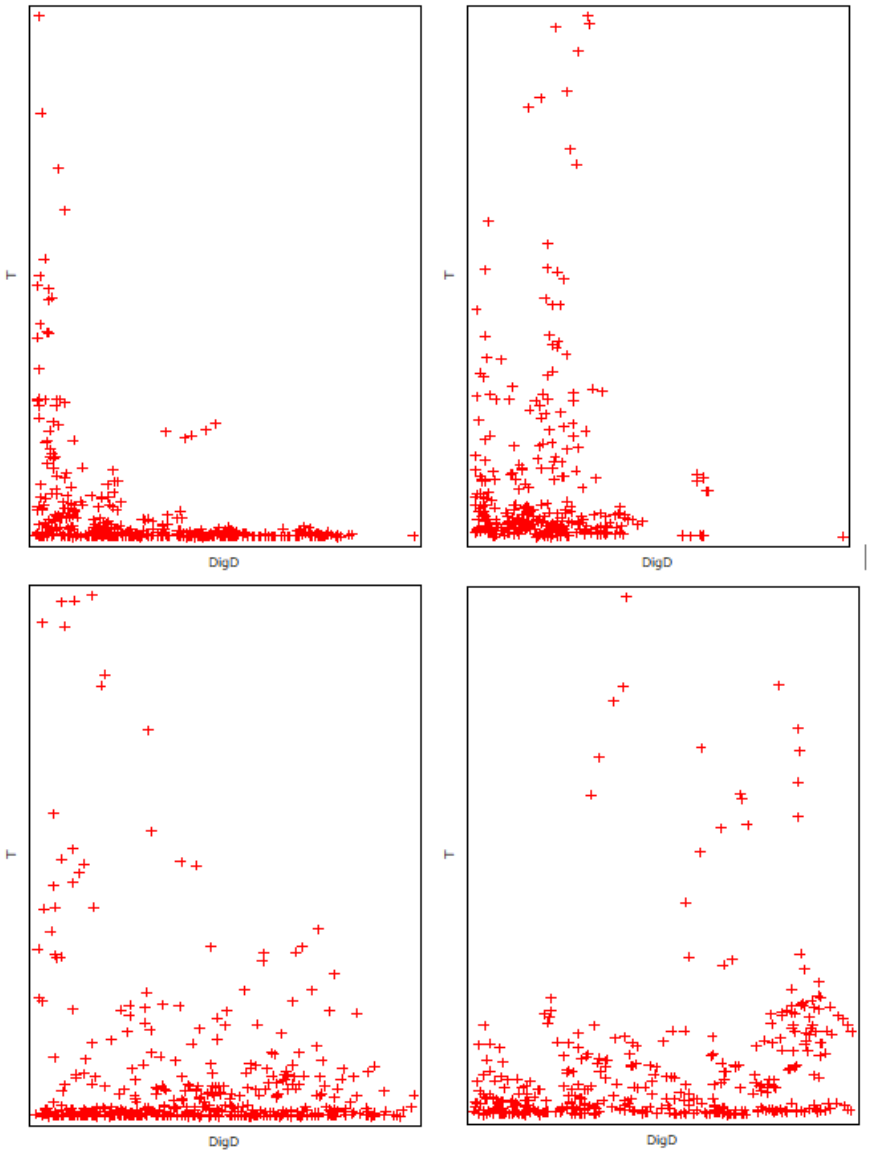

Figure 1. Spread of digital distance data for Norway, Russia, Georgia and India.

Source: compiled by the authors on the basis of [18-21, 23].

Fig. 1 shows a significant spread of data in the assessment of trade turnover of countries with a digital distance. The obtained results allow us to draw a conclusion about the need to take into account this feature and the use of generalized (weighted) least squares method under heteroskedasticity conditions which will reduce the variance in the calculations.

Table 2. Results of calculations of the gravitational equation in the conditions of digitalization of the world economy (IMNC).

	Norway	Russia	Georgia	India
const	500,088**	−3128,53***	15262,9***	12421,8***
GDP 1	0,00258879***	0,00444189***	-	-
GDP 2	0,000850296***	0,00381188***	0,0396484***	0,02***
Dig D	−389,964***	−1051,99***	-	1620,28 *
CB	2337,06**	6319,19***	828394***	21843,8***
CL	-	13760,0***	-	-
Integr	−659,892***	-	-	−10715,9 *
R^2	0,68	0,57	0,65	0,69
0	440	320	445	415

Source: compiled by the authors on the basis of [18-24]

Note: P-value– 0,05 (***), 0,10 (**), 0,15 (*).

The calculations made make it possible to significantly increase the coefficient of determination for all states except Georgia. Moreover, the elasticity coefficients of the gravitational equation indicators have significantly decreased, which allows to minimize alternative ways of events development. The structural role of digital distance has remained unchanged. However, now we can see the relationship between the level of digitalization of the country's economy and the role of digital distance in foreign economic policy: developed countries in foreign trade are mainly focused on States of approximately identical level of digital development.

It should be noted that the gravitational equation used by the authors is not applicable for the Georgian economy. Probably the reason is the low sample size in the small scale of the digital sector in the economy.

3.3. Peculiarities of bilateralism in the conditions of global digitalization

Gravitational equations often have a number of additional criteria that necessitate the use of certain parameters in the evaluation of economic processes. The specification proposed by us is no exception.

In modern conditions of existence of the world economy it is not always possible to argue the reasons of economic actions. Different types of bilateral economic relations have individual characteristics that generate multifactorial economy. Let us consider in detail the directions of foreign economic activity of Norway, Russia and India to identify the position of the digital economy in the systemic diversity of existing States.

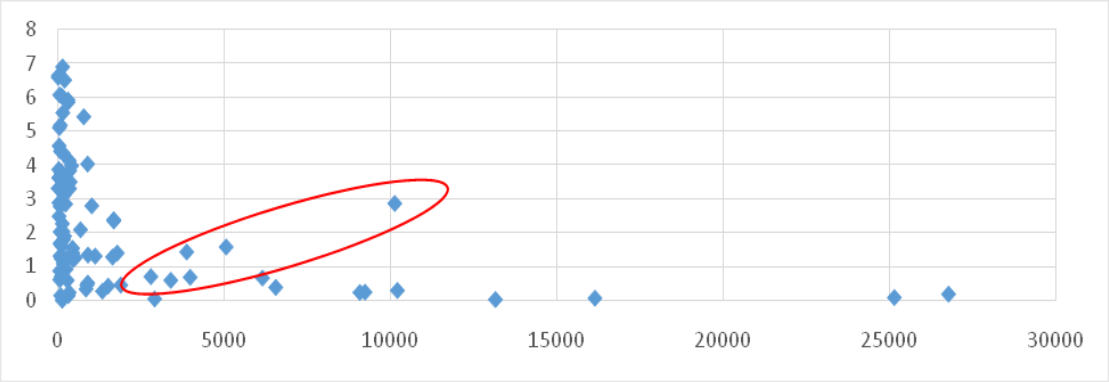

Figure 2. The dependence of the turnover from digital distances in Norway (units/million USD) Source: compiled by the authors on the basis of [18,23].

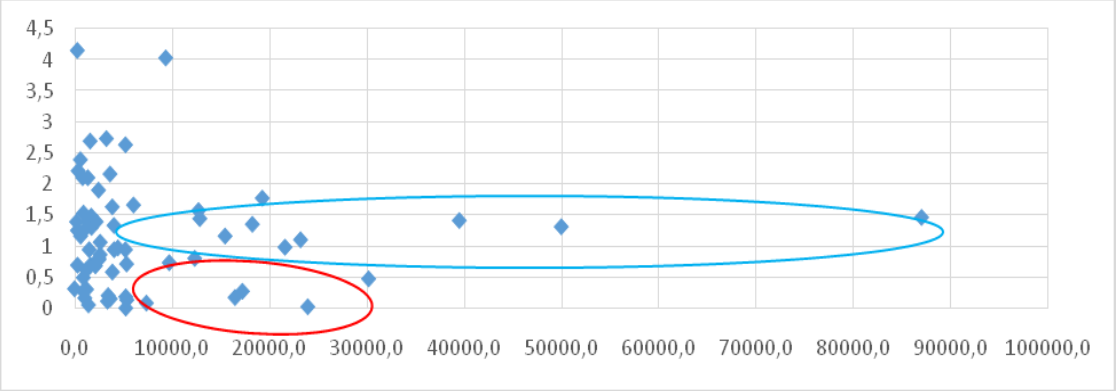

Figure 3. The dependence of the turnover from digital distances in Russia (units/million. USD) Source: compiled by the authors on the basis of [19,23].

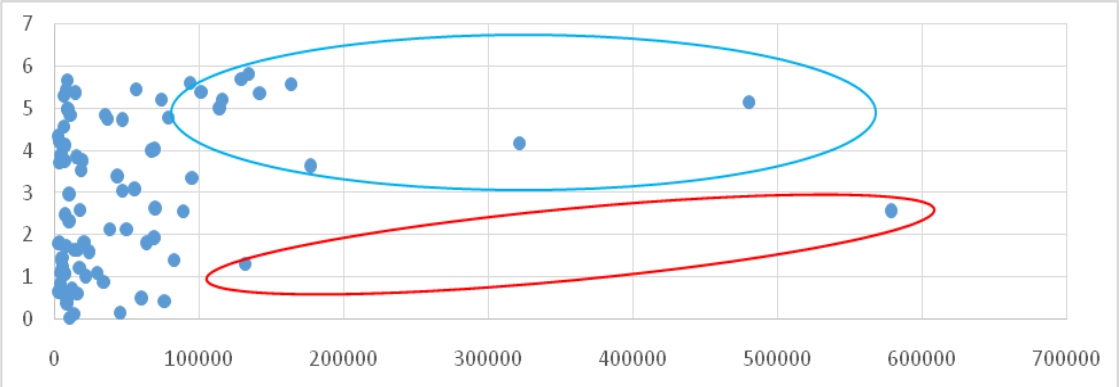

Figure 4. The dependence of the turnover from digital distances in India. (units/million USD). Source: compiled by the authors on the basis of [21,23].

In Norway only three of the 15 main trading partners go beyond a single digital distance. The average value of this indicator among Norway's five largest partners is 0.13. These countries (UK, Germany, Sweden, Holland, USA) make up 50 % of Norway's trade turnover. China has an exceptional character for the state economy, the foreign economic role of which is now global. From China to Norway deliveries of products of mechanical engineering and transport equipment are carried out [18].

Russia has a more significant breadth of indicators. So 10 of the 15 major trading partners go outside the unit. At the same time, the main segment of the country's foreign economic activity (51 % of trade) is in the range from 1 to 2. The exception (DigD to 1) are countries located in relative geo-

graphical proximity, and having stable economic relations with Russia (Belarus, Kazakhstan, Poland, Turkey, etc.) [19].

India as a state with a low degree of development of the digital economy is focused on trade with countries of the diametrically opposite level of digitalization. 10 of the 13 major trading partners (37% of the country's turnover) have a digital distance difference with India of more than 4. The values of China and Indonesia do not fit into the common coordinate system. The reason for this is the system-forming position of China in the import of India and large volumes of imports of palm oil and coal briquettes from Indonesia [21].

The obtained data allow us to highlight some features of bilateral economic relations in the conditions of digitalization of the world economy:

• The geographical factor still occupies a special place in the foreign economic policy of the state. However, its role is declining with the development of the digital economy, giving place to a digital distance.

• Despite the increased pace of development of the digital economy, even in the most developed countries in the context of globalization, there will be significant amounts of foreign economic transactions of a market nature ensuring the functioning of the economy.

• The presence of an insignificant volume of bilateral relations between countries with a low level of development of the digital economy, due to the gravitational affiliation of States to the hegemons of a higher digital level

4. Conclusion

This study attempts to assess the situation of the digital economy in the study of bilateral economic cooperation of countries in the context of globalization. The widely used gravitational equation has been transformed taking into account the indicators of digital dependence. Based on the analysis of foreign trade of Norway, Russia, Georgia and India, the success of the developed specification was conditionally confirmed.

The results allowed us to conclude about the desire of developed digital powers to cooperate with countries of similar digital level ($DigD \leq 1$). At the same time, countries with a lower level of digitalization have a wider range of digital distances which is reduced as the level of development of the digital economy increases which indicates the desire for economic growth in the conditions of the impossibility of abandoning the economy-forming non-digital segments.

Despite this, geographical distance as the basis of economic interaction of States has a significant impact on the process of choosing the vector of economic policy. However, its role is gradually decreasing.

It should also be taken into account that this study opens a number of further directions in the study of issues of bilateralism in the era of the digital economy, including:

- Evaluation of the value of the digital distance from the position of the scale of the state economy.

It is necessary to identify the degree of differences in foreign economic policy of large and small economies in the conditions of strengthening the digital sector. The data obtained will allow to interpret the results of the current study at the global level.

- Identification of additional indicators reflecting the importance of the digital economy in determining the direction of bilateral economic relations.

The complete set of the gravitational equation in this direction will allow to minimize the probability of error of calculations when making forecasts of foreign economic activity.

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