THE USE OF GRAVITY MODELS FOR MANAGING ECONOMY IN THE CONDITIONS OF INSTABILITY

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Abstract. This article deals with theoretical and methodological aspects of gravity models.A number of economic indicators such as capital investments, the average salary, gross regional product, the income of the population, the volume of the sold industrial outputin Ukraineare described. The gravity modelsused to manage the Ukrainian economy nowadays arepresented.

Keywords: gravity model, modeling the economy, capital investments, the average salary, regional product gross, income of the population, volume of industrial product sales.

DOI: http://dx.doi.org/10.23856/2105

Introduction

The defining feature of the economic system of Ukraine nowadays is instability, which may have different origins and is conditioned by the whole set of factors. Reflecting the objective laws of economic system the instability significantly complicates the activities of enterprises or organizations, confuses in choosing strategic priorities, justification of administrative policy and approaches to its formation and implementation.

In the absence of full market institutions, the instability of the environment causes much more real and potential threat to the efficient and competitive development of the enterprises or organizations. This feature clearly distinguishes the economic system of Ukraine. For many years the environment of enterprises or organizations has been characterized by complexity and considerable uncertainty, as evidenced by various international rankings including global competitiveness ranking of the World Economic Forum and the rating of 'Doing Business'. The reason for such situation is the totally inadequate, inconsistent and unpredictable policy of the government as the subject of regulation. Thus, the tasks of finding models of adaptive management companies, which would allow effective resistingthe impact of external destabilizing factors, are becoming much more urgent.

For developing specific policies on trade relations in different regions of the country we need to makethe preliminary analysis of the economy. That is why the task of the comprehensive study of economic relations and Economic Modeling is very important. Therefore, the role and the use of gravity models as the way of research for the best modeling of the overall picture of the development and prospects for the future of the economy of Ukraine will be considered in this article.

The importance of this problemcan be explained by the fact that in times of economic instability the usage of gravity models for modeling economy is rather crucial. It is a fundamentally new factor that can affect positively or negatively the activities of not only Ukrainian enterprises but industries and the economy as a whole. The gravity model describing social and economic interaction between different objects (cities and regions) gives the opportunity to analyze and preserve the economic environment that improves the economic stability in Ukraine. This model is called "gravity" because of its obvious resemblance to Newton's law of universal gravitation. Currently, the model has become widely used for the assessment of trade flows and it is spread thanks to its high empirical accuracy. The advantage of this model is its rigorous theoretical justification. The model has many different versions, which are used to analyze the process of urbanization andstudy export-import relationships, location of industry and population migration.

Theoretical and methodological aspects of gravity models

This article deals with theoretical and methodological aspects of gravity models regarding the economic performance in terms of instability. As we have examined the essence of the concept of "gravity model" we would like to present the classification of gravitational models and the distinctive features of these models.

The most popular directions of the practical use of gravity models relate to valuation of:

- the impact of economic fluctuations;
- the impact of policy variables;
- formation of integration associations.

Among the scientists involved in the developments of gravity models in analyzing the structural transformations of economic systems, are the following: William Ayzard (2009), D. Anderson (1999), D. Berhstrand (2000), B. Moskovkin (2000), D. Stewart (2008) and others.

Gravity models are used to describe and predict various social and economic interactions between the districts of the city and are based on the assumption that the value (force) of their interaction is proportional to the product indicators of the districts population and is inversely proportional to the distance between them:

$$M_{ij} = k\frac{p_i p_j}{d_{ij}^2} \quad (1)$$

where Pi, Pj - the population of districts i and j; dij - distances between the districts i and j; Mij - an indicator of interaction between the districts i and j (for example, the number of trips); k - the normalizing parameter.

The American sociologist F. Kerry in the middle of the XIXth century noted the presence of the analogue of the gravitational force in public events. In 1929, C. Reilly (USA) suggested the retail gravitation law under which with the help of its retail trade the city

attracts the customer base from the surrounding area with the "force" proportional to the size of the city and inversely proportional to the distance from customers to the city center. The border areas of sales of the cities i and j is defined as the locus of points for which:

$$\frac{p_i}{d_{i,x}^2} = \frac{p_j}{d_{j,x}^2} \tag{2}$$

where di,x, dj,x – the distance between cities i and j, according to point x on the boundary.

The theory of gravity model was elaborated by D. Stewart (USA). His idea was that the interaction between people submits to the law, similar to the law of universal gravitation. Together with the concept of demographic forces he suggested the formula for demographic potential calculation:

$$v^x = \sum_i v_i^x \tag{3}$$

D. Stewart designed the maps of demographic potential for the United States. Later similar maps have constantly been updated in many countries of the world. It has been proved that the demographic potential reflects the development of the area better than the generally accepted rate of population density. He also noted a high correlation of demographic potential with the developmentof retail trade, roads and rural employment in non-agricultural sectors.

Gravity models with the appropriate selection of the parameters are widely used to describe the interaction of the migration process. They are well applied for calculation of long distance telephone calls, shopping trips and commuting migration. The development of the simplest gravity model took place in several directions:

1. In addition to the indicators of the population and distances other factors such as the ratio of increases of investments in the districts, the number of vacancies or, on the contrary, the share of the unemployed within working population and the number of vacancies within the way from one district to another (model of intermediate possibilities) were included in the above-mentioned model.

2. Gravity model is used in cases where the indicators of districts' population are given some advantages. A simple example of joint application of both areas provides a model that describes the number of trips between the US states:

$$M_{i,j} = k\frac{(w_i p_i)\cdot(w_j p_j)}{d_{i,j}^2} \tag{4}$$

3. The design of such gravity models is often included in a variety of model complexes for describing the processes of urban and regional development.

To analyze the general patterns of population distribution in accordance with the major system function of the city on its territory the models of urban spatial development are used. The informational modelwas used to solve these problems, so thegraphaccording totheaimofthetaskshows the next parameters:

- concentration of population (depending of the place);
- a number of places of cultural and community or recreational services;
- a number of jobs.

Except the above mentioned application, gravity models are used in logistics, for example, they are applied to search for the place of the location of a single warehouse, which provides supplies for different retail sellers. In this case, the gravity model is represented as an average weighted quantity. The placement of retail warehouses, the volume of transported

goods and the cost of transportation according to the estimated location of the central warehouse are taken into account. On the first step to the solution of this problem several options for placing the central warehouse in the system of coordinates are offered. The beginning of coordinate system and used scale are agreed on the basis of the correct submission of relative distances. This is done, for example, by imposing certain scale grid on the map.

As a result of our studythe classical gravity model regarding regional centers of Ukraine was built, as well as gravitational models were created on the basis of economic indicators. The task of our article was to analyze the economy of Ukraine and to develop a rating of regional centers by means of these models.

The classical gravity model was createdupon using the given formula (1). The calculations of the model helped to make the Grade of the regional centers of Ukraine. In its turn, it gave us the opportunity to have the overall picture of the gravitational forces between the cities. So, the rating of Ukrainian cities is as follows:

Table 1

Rating score of regional centers of Ukraine regarding classical gravity model

№	City	Rating points	№	City	Rating points
1	Kyiv	100	14	Vinnytsia	20,32
2	Dnipro	97,71	15	Cherkasy	19,46
3	Zaporizhzhya	76,17	16	Kropyvnytskyi	18,17
4	Kharkiv	57,47	17	Luhansk	15,74
5	Mykolaiv	57,00	18	Rivne	13,42
6	Kryvyi Rih	44,98	19	Lutsk	12,44
7	Kherson	40,40	20	Ternopil	12,30
8	Odesa	38,25	21	Khmelnytskyi	11,54
9	Donetsk	32,73	22	Sumy	11,51
10	Zhytomyr	25,28	23	Ivano-Frankivsk	9,27
11	Lviv	21,99	24	Chernivtsi	5,52
12	Poltava	21,86	25	Uzhhorod	1,53
13	Chernihiv	20,72			

So, with the given rating we may conclude that the capital of Ukraine, Kyiv, has the greatest gravitational force. The top five includes the following cities: Dnipro, Zaporizhzhia, Kharkiv, Mykolaiv.The classical model made without taking into account any extraneous factors or indicators. was considered above. Next, let us consider the gravity modelsaccording to the economic indicators.

The first model is a gravity model based on the capital investments (4). The capital investments are money allocated for the reproduction of fixed assets, expansion, reconstruction and modernization of enterprises and facilities, technical progress in all sectors of the economy, the construction of housing, schools, hospitals and other social and cultural

destinations, geological prospecting and architectural design. That is, capital investments are mainly the funds used to increase fixed assets, other non-current tangible assets, intangible assets, and for their reconstruction and modernization, leading to the increase of the initially expected future economic benefits. The ultimate goal of the capital investments is the expanded social production.

Capital investments play a crucial role in the economy of the country, the city and any company, as they are the basis for:

- systematic recovery of fixed assets of the enterprise and implementing policies of expanded reproduction;
- accelerating scientific and technological progress and improving product quality;
- structural restructuring of social production and sustainable development of all sectors of the economy;
- creation of necessary resource base for industry;
- civil construction, development of Healthcare, higher and secondary schools;
- mitigating or solving the problem of unemployment;
- protection of the environment and achieving other goals.

Thus, the investments are needed primarily for economic recovery of the city and the country in general, and on this basis for solving many social problems, especially for rising living standards.

As the similar ranking of cities was drafted, with the help of the latter it is possible to estimate in which cities of Ukraine there is a stronger gravitational force based on capital investments. The rating of cities is as follows:

Table 2

The rating system of regional centers of Ukraine regarding the gravity model using capital investments

№	City	Rating points	№	City	Rating points
1	Kyiv	100	14	Donetsk	3,36
2	Dnipro	37,25	15	Kropyvnytskyi	2,25
3	Kharkiv	34,62	16	Khmelnytskyi	2,25
4	Zaporizhzhya	17,90	17	Kherson	2,08
5	Kryvyi Rih	16,78	18	Sumy	1,57
6	Odesa	14,99	19	Lutsk	0,96
7	Mykolaiv	8,70	20	Rivne	0,94
8	Chernihiv	7,09	21	Ivano-Frankivsk	0,64
9	Zhytomyr	6,94	22	Ternopil	0,62
10	Lviv	5,38	23	Luhansk	0,34
11	Cherkasy	4,62	24	Chernivtsi	0,16
12	Vinnytsia	4,55	25	Uzhhorod	0,03
13	Poltava	4,47			

The second model is the gravity model considering the average wage rate (4). The salary is one of the main factors of socio-economic life of each country, staff and people. High wages can make a positive impact on the economy as a whole, providing a high demand for goods and services. Finally, higher wages stimulate efforts of the managers to use workforce carefully and upgrade their production.

Wages is a connecting element between the state,the city, and an enterprise. It is the incentive for productivity growth and an important element of production costs. Wages form the level of the material wellfare of workers. Nowadays the salary remains for the people of our country the main source of income and support of living standards, because wages in aggregate income holds the largest share in average 43%. It is not only an indicator that determines the overall standard of living of workers. The state of wages and forms of implementation, the share of the gross national product depend largely on the possibilities of economic development in general.

We drafted the ranking of cities that allows defining in which cities of Ukraine there is a stronger gravitational force based on the average monthly salary. So, the rating of the cities is as follows:

Table. 3

Rating system of regional centers of Ukraine regarding the gravity model considering the average monthly salary

№	City	Rating points	№	City	Rating points
1	Kyiv	100	14	Kropyvnytskyi	16,35
2	Dnipro	80,43	15	Vinnytsia	16,22
3	Zaporizhzhya	53,03	16	Cherkasy	14,73
4	Mykolaiv	45,36	17	Luhansk	13,28
5	Kharkiv	44,69	18	Khmelnytskyi	10,93
6	Odesa	38,01	19	Ternopil	9,33
7	Kryvyi Rih	31,00	20	Rivne	8,95
8	Kherson	30,09	21	Lutsk	8,61
9	Zhytomyr	25,06	22	Sumy	7,96
10	Donetsk	23,89	23	Ivano-Frankivsk	6,70
11	Lviv	17,04	24	Chernivtsi	4,34
12	Chernihiv	16,88	25	Uzhhorod	1,18
13	Poltava	16,72			

The third model is a gravity model taking into account the gross regional product (4). At the regional level the summary measure that reflects the level of economic development of the region, is the gross regional product (GRP). Its value in market prices is defined as the sum of gross and added value of all economic activities, including net taxes on products (Pribytkova, 2007) The given indicator shows everythingproduced in this region during the

year. Numerous studies show significant disparities of regional development in Ukraine. Gross regional product (GRP) is a summary measure of economic activity in the region, describing the process of production of goods and services.

Without GRP construction of major national accounts is impossible. In Ukraine GRP calculation method is mixed, which means that a piece of data (that usually refers to non-financial corporations, municipal and government transactions) is accumulated by regional statistical agencies and is sent to the center, but some other data are collected by the State Statistics Committee due to other sectors.

Thus, the ranking of cities was drafted which allows to estimate in which cities of Ukraine there is a stronger gravitational forcebased on the gross regional product. The rating of cities is as follows:

Table 4

The rating system of regional centers of Ukraine regarding the gravity model using GRP

№	City	Rating points	№	City	Rating points
1	Kyiv	100	14	Kherson	4,37
2	Dnipro	27,61	15	Lviv	3,93
3	Kharkiv	24,80	16	Donetsk	3,40
4	Zaporizhzhya	16,14	17	Sumy	2,78
5	Chernihiv	14,23	18	Khmelnytskyi	2,35
6	Odesa	12,35	19	Rivne	2,17
7	Zhytomyr	12,34	20	Lutsk	1,31
8	Kryvyi Rih	10,16	21	Ternopil	1,01
9	Mykolaiv	9,90	22	Ivano-Frankivsk	0,89
10	Cherkasy	8,43	23	Luhansk	0,62
11	Kropyvnytskyi	7,87	24	Chernivtsi	0,44
12	Poltava	6,24	25	Uzhhorod	0,06
13	Vinnytsia	5,71			

Having considered all data we can conclude that the level of the most developed economy is observed in Kyiv, Dnipro, Kharkiv, Zaporizhia and Chernihiv.

The fourth model is the gravity model considering the income of population living in given cities (4). The income of the populationis theset of money and monetary receipts to support physical, moral, economic and intellectual condition of people and satisfy their needs.

The incomes are formed due to the payment, the payment of social funds (regional, local, and consumption funds of enterprises and organizations), business income, the income from personal subsidiary house holding and self-employment, as well as from other sources. The sums of incomes and their distribution directly affect the formation, development and use of labor potential of society.

Highly developed countries with high-income andtheir moderate differentiation, as a rule, have powerful employment potential (Canada, Switzerland, Finland, Sweden, Japan, Germany, etc.). The problems of incomes and living standards take a leading position in the

system of labor potential of society. It would be reasonable to consider the gravity model regarding this important indicator.

Thus, the ranking of cities which allows estimating in which cities of Ukraine there is a stronger gravitational force based on the income was built. The rating of cities is as follows:

Table. 5

The rating system of regional centers of Ukraine regarding the gravity model using incomes

№	City	Rating points	№	City	Rating points
1	Kyiv	100	14	Poltava	5,21
2	Dnipro	28,48	15	Lviv	4,86
3	Kharkiv	25,69	16	Sumy	3,68
4	Zaporizhzhya	19,04	17	Donetsk	3,42
5	Chernihiv	16,20	18	Khmelnytskyi	3,22
6	Odesa	16,00	19	Rivne	2,70
7	Mykolaiv	14,41	20	Lutsk	1,73
8	Zhytomyr	12,92	21	Ternopil	1,51
9	Kryvyi Rih	9,14	22	Ivano-Frankivsk	1,12
10	Cherkasy	8,20	23	Chernivtsi	0,87
11	Kropyvnytskyi	8,16	24	Luhansk	0,85
12	Kherson	8,03	25	Uzhhorod	0,09
13	Vinnytsia	6,90			

The fifth model is the gravity model considering the volume of industrial products (4). Industrial production is the useful direct result of industrial and production activities of enterprises in the form of finished products, semi-finished products by means of works and services of industrial character and balance of work in progress. The realized products are products that came in that period to the market and must be paid by consumers. In current conditions the quality of products and services is one of the most important factors in the successful activity of the enterprise or organization.

The data on volume of sales of industrial products of enterprises allow estimating the degree of penetration on the market, formed market situation, competitive position in the market and economic development of the commercial enterprise.

So, the volume of sales of industrial products is one of the determining factors of the efficiency of industrial enterprises, the starting point for determining the resource potential of the company, one of the main factors determining the value of the cost of resources and so on. That is why the model considering the volume of realized industrial production was chosen to determine the gravitational force.

The ranking of cities which allows assessing in which cities of Ukraine there is a stronger gravitational forcebased on the volume of realized industrial production was made. The rating of cities is as follows:

Table 6

The rating system of regional centers of Ukraine regarding the gravity model using the volume of industrial products

№	City	Rating points	№	City	Rating points
1	Dnipro	100	14	Lviv	1,92
2	Zaporizhzhya	56,22	15	Kherson	1,69
3	Kyiv	42,99	16	Kropyvnytskyi	1,54
4	Kharkiv	36,30	17	Sumy	1,11
5	Kryvyi Rih	26,95	18	Luhansk	1,03
6	Donetsk	13,88	19	Khmelnytskyi	0,64
7	Poltava	6,71	20	Rivne	0,53
8	Odesa	5,02	21	Ivano-Frankivsk	0,32
9	Mykolaiv	4,77	22	Lutsk	0,28
10	Cherkasy	3,17	23	Ternopil	0,17
11	Zhytomyr	2,78	24	Chernivtsi	0,09
12	Vinnytsia	2,10	25	Uzhhorod	0,01
13	Chernihiv	2,09			

Conclusions

As a result, six gravity models that allow making a qualitative analysis for the future, concerning the development and prospects of regional centers of Ukraine and the economy in general, since the analysis of small towns has no importance, were built.On the basis of data obtained the graph that shows the ratio of calculated ratings of regional centers of Ukraine was built.

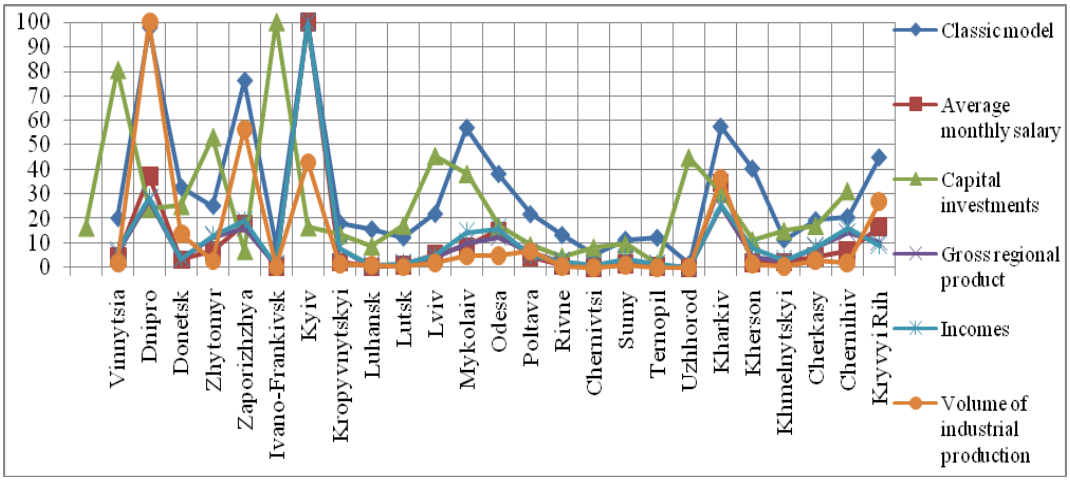

Fig. 1. The rating graph of regional centers of Ukraine

From the graphthree city leaders can be revealed. They are Dnipro, Zaporizhzhia and Kyiv, they have the highest results. Kyiv is leading in almost every rating assessment and has got 100 points that is the maximum rating. Only the model based on the volume of the implemented industrial production shows its 42.99 points. The other three cities: Mykolaiv, Kharkiv and Kryvyi Rih also have got good points. Uzhgorod takes the last place regarding all economic indicators that showsthe low level of the income and standards of living.In the given article the role and use of gravity models as the research method for the best modeling of the overall picture and prospects for the future concerning the economy of Ukraine were considered. The use of gravity models to model the economy is rather important and fundamentally new factor that can affect positively or negatively the activities of not only Ukrainian enterprises but industries and the economy as a whole.

Thus, the study of gravity models allows making conclusion about their widespread use in modeling trade relations, not only at international but also at other levels,for instance, regional and city ones.

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