

# “Methodology of national investment and innovation security analytics”

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# METHODOLOGY OF NATIONAL INVESTMENT AND INNOVATION SECURITY ANALYTICS

## Abstract

The main problem of the research is development of a conceptual framework for investment and innovation security, as well as the methodological approach to its assessment, which will allow monitoring and identifying the threats and achieving the desired security state of the national economy. It has been proved that investment and innovation security is a multi-level phenomenon, consisting of the following levels: global, national, corporate and household ones. Investment and innovation security is determined by three components, such as state security at the external and internal markets, security of enterprises (corporations) and individual households, which requires their balancing. The methodical approach to the integrated assessment of the investment and innovation security level is developed, which involves the development of integral index as the geometric mean of 3 sub-indices, which include single indices under the national, corporate and household level. The results of this methodological approach approbation allowed us to form preconditions for finding ways of growth, forecasting trends and building scenarios for strengthening the investment and economic security of Ukraine.

## Keywords

investment and innovation security, strategy, assessment, indices

## JEL Classification

F52, O31, R42

## INTRODUCTION

The interdependent connection of investment and innovation processes within the national economy, their significant coverage of the economic system make it possible to determine the reasonability of considering the investment and innovation component of economic security and the definition of opportunities and priorities for ensuring the safety of these processes within the national economy, as well as investment and innovation policy of the state oriented on its economic security, the development of appropriate indices and mechanisms for achieving them. The aforesaid information requires an objective and comprehensive monitoring of the economy using the economic security indicators, which involves, first of all, actual tracking, analysis and forecasting of the most important groups of economic indices (indicators), as well as the implementation of specially designed mechanisms for countering threats and achieving a stable state of the economy.

Social transformations in transformational economies change views on its essence, shifting the emphasis from national security to individual security, which involves reconciling social and individual interests during the periods of economic shocks and economic instability. New understanding requires the precise approaches to the monitoring of economic security and, on this basis, the formation of a strategy for the relevant investment and innovation policy. Previously, the sphere

of economic security was the prerogative of the government, which allowed it to be influenced by the means and instruments of economic policy that were part of the state economic strategy.

The main scientific problem is the need to identify modern social aspects of investment and innovation security and to develop methods for its diagnostics, which will allow monitoring, identifying security threats and achieving the desired security state of the national economy.

## Aims

The first part of this study is aimed at revealing modern features of understanding the essence of economic security in the world economic thought and a comparison of methods for assessing the economic security level, and the definition of an approximate list of indices characterizing the investment and innovation security. In the last part, the authors suggest their own methodology for assessing the investment and innovation security of the national economy based on the use of integral index.

## 1. LITERATURE REVIEW

The literature distinguishes three main approaches to economic security, such as:

- 1) Anglo-american;
- 2) European;
- 3) Asian (Ioan-Franc & Diamescu, 2010).

The content of these approaches is determined by the basic principles of different types of economic systems. In particular, the Anglo-American market system is based on private ownership and the satisfaction of the needs of consumers and the realization of the interests of producers, that's why its goal is not to build an economy ready for military needs, but to develop public welfare.

In contrast to the approach considered, the Asian approach is based on strict control of economic processes by the state, which leads to the restriction of citizens' freedoms and the formation of opportunities for the economic potential formation at the national level.

The European approach is for the most part a combination of the two previously considered ones. On the one hand, individuals and producers are provided with opportunities for individual economic activity, and on the other hand, the state has enough regulatory influence to generate sufficient economic power to ensure national security.

In accordance with the established approaches at the level of economic systems to the formation of

the economic security system, in the economic literature, the fundamentally different definition of the essence and content of economic security was formed. We distinguish three relevant basic approaches to the consideration of the essence of economic security (see Table 1).

**Table 1.** Approaches to understanding the essence of the concept of "economic security"

Author(s)	The essence of the concept of "economic security"
Dixit (2011), Stoian and Vickerman (2005), Wehrle and Pohl (2016)	Economic security is considered at the national level as a system of protection against external threats
Mares (2004), Osberg (1998), Hacker, Huber et al. (2012), Wysokińska-Senkus and Raczkowski (2013), Nef (1999), Stiglitz, Sen, and Fitoussi (2009)	Economic security is considered in social terms as the need to protect the economic well-being of individuals. Mostly is characterized by a term of economic insecurity and reflects the Anglo-American approach
Moiseenko and Ryvak (2012), Kharazishvili (2014), Antropova and others (2015), Zukrowska (1999), Grigoreva and Garifova (2015), Poirson (1998), Kharlamova (2014), Momot and Avanesova (2016), Simanavičienė and Stankevičius (2015), Baranovskyi and Moroz (2017), Stankevičienė et al. (2013), Ioan-Franc and Diamescu (2010)	Economic security is defined as a system of state economic means for ensuring economic stability and the formation of economic power at the state level. Typical for the European and Asian approaches depending on the context of its application

According to the first approach, economic security is considered as a system of protection of national sovereignty, which involves formation of a set of investment policy means aimed at reducing dependence on foreign investors (protection against

the threat of loss of control over key sectors of the economy). Researchers of economically developed countries associate the economic security of countries with the threats from foreign investors (individuals and states) (Dixit, 2011) and, accordingly, define means aimed at overcoming these threats, namely legal restrictions on the possession or acquisition of assets by foreigners or the government's assessment of risks associated with foreign investment (Wehrle & Pohl, 2016, p. 11). At the same time, economists, by conducting research on the basis of data obtained from the countries of Central and Eastern Europe, consider a two-way link between the economic security level and attraction of foreign direct investment, focusing on whether it is possible to attract more direct foreign investment on the basis of solving problems of economic security (Stoian & Vickerman, 2005).

For the second approach, typical is the emphasis on the foreground of the individual's economic security, which on the micro level depends directly on the level of its welfare, and at the macro level – on the level of social protection and indices of economic growth. In particular, it is emphasized that a person is economically unprotected in case he/she is exposed to a risk due to economic uncertainty that one cannot ignore or overcome (Hacker et al., 2012, p. 4; Osberg, 1998, p. 7). In fact, its presence reduces the well-being of certain individuals, which should be within view of the welfare state (Osberg, 1998, p. 13). This is also Stiglitz, Sen, and Fitoussi (2009) specifying that risks are primarily related to unemployment, illness, and old age. The content of economic security of the state through the level of social protection of certain individuals was more detailed considered by Nef (1999) who noted that since the 1930s, the level of economic security was measured by the amount of per capita income, expanded its measurement further to the physical, economic, social, political and cultural security of the individual. Confirmation of the interdependence of the individual's economic security and economic security of the state, which is manifested in the general level of prosperity in the state and its sustainable development, has been proved in a number of studies, in particular Mares (2004), Wysokińska-Senkus and Raczkowski (2013), which leads to understanding the need to increase the level of social protection of the population in order to ensure an adequate level of economic security of the state.

The third approach is aimed at highlighting economic security as a concept close to national security, based on the state use of a set of means aimed at creating economic preconditions for building a powerful and stable state. Economic security is characterized by an entire set of macroeconomic indices reflecting its current state and threats to a stable economic functioning of the state, its competitiveness (Grigoreva & Garifova, 2015; Kharazishvili, 2014; Moiseenko & Ryvak, 2012; Simanavičienė & Stankevicius, 2015). Zukrowska (1999) also pays attention to the problem of macroeconomic stability and its dependence on the economic security level and at the same time states that an economically stable state can easily adapt its military needs in accordance with the threats. Along with this an integrated approach that considers economic security as a state of the economy, which promotes both socio-economic stability, social well-being and the ability of the state to withstand military threats, is distinguished (Ioan-Franc & Diamescu, 2010). Thus, there are also researchers who, without emphasizing the attention in some aspects, define economic security as a state of protection against external and internal threats (Momot & Avanesova, 2016; Stankevičienė, Sviderskė, & Miečinskienė, 2013).

Having considered the basic approaches to the essence of economic security, it may be affirmed that generally everything depends on the type of state structure and cultural advantages: should public or private interests have top priority. Taking Ukraine as an example, the inheritance of the totalitarian past is obvious, when most of the state interests are set higher than private ones. At the same time, there is a noticeable movement towards democratization of society, which gradually places a premium on private interests. Resolving this dilemma in the conditions of geopolitical threats and internal contradictions in Ukraine, it is expedient to synthesize these approaches, which is close to the European approach to economic security.

## 2. METHODS

The economic entities act effectively under certain parameters, the overrun of which threatens both their efficiency and the very existence of them, that is, poses a threat to their economic securi-

ty. The possibility of their quantitative and qualitative description can determine the economic security criteria on the basis of setting threshold values. When the economic entity overruns them, it means a violation of economic security. The deterioration of indices, depending on changes in certain indicators, allows us to develop appropriate stabilizing (anti-crisis) measures. It should be a permanent object of the monitoring and management system.

Understanding the economic security essence allows to describe the required state, limited by parameters and to determine the indicators that characterize it.

The theoretical significance of economic security is a complex subject of the research and causes a variety of approaches to its comprehension. Generally, economic security implies the formation of an economic situation, being the basis of social and economic stability, favorable living conditions, political and military power of the state.

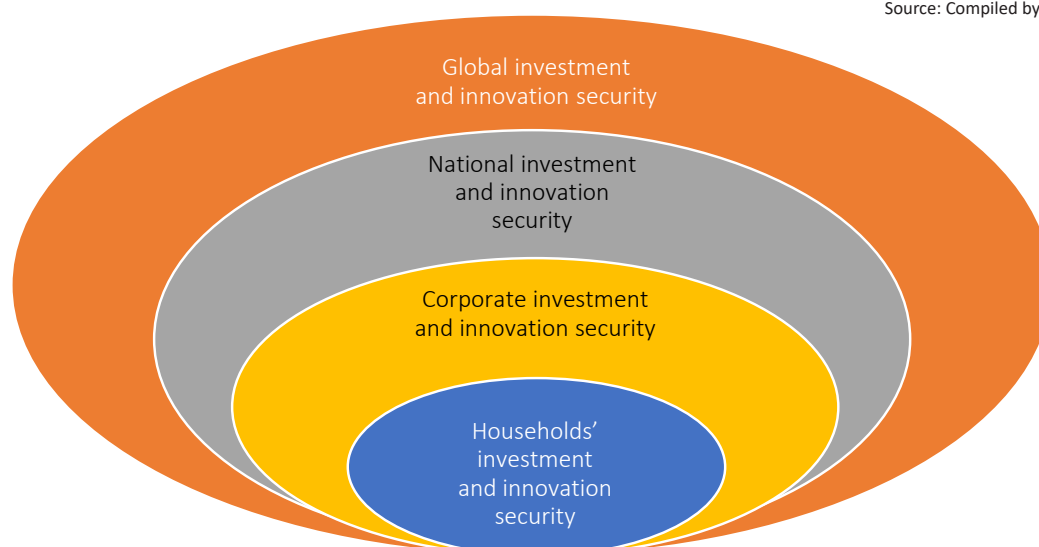
### 3. RESULTS

Proceeding from the above, we can offer our own author's approach to understanding the essence of economic security – it is a state of the economy, determined by the way of its functioning and opportunities for sustainable development in the

conditions of negative influence of external and internal factors and realization of social and individual interests in their interconnection.

An integral part of the economic security system is the investment and innovation component, as in this field the conditions for improving the investment climate, balancing the investment support of the economy, gaining competitive advantages in the global market, as well as conditions for the national economy development, improvement and acquisition of new forms, methods and means of its functioning, are formed. There is a strong interrelation between the investment processes dynamics and the characteristics of technological transformations and the growth of the economy: the investment activity increases – the economy grows; the innovation activity grows – the national economy are gaining competitive advantages. The confirmation of this can be found also in some studies (Antropova et al., 2015; Kharlamova, 2014; Poirson, 1998; Simanavičienė & Stankevicius, 2015). In fact, investments and innovations are considered in modern economic conditions as important instruments for the formation of stable economy and the avoidance of economic shocks. Based on the above interconnections it can be affirmed that, like the national economy, investment and innovation security is a multi-level phenomenon. It includes the following levels: global, national, corporate and household (see Figure 1).

Source: Compiled by the authors.



**Figure 1.** Levelled structure of investment and innovation security of the national economy

Investment and innovation security is determined by three components, namely national security in the external and internal markets, corporate security and households' security, which demands their balancing. Therefore, the investment and innovation security is a complex structure for assessment. It involves protecting the interests of all three groups of economic agents: public institutions provide it at the global, national and regional level; stimulating the production, distribution and consumption of goods and services produced by a national economy as a result of the interaction of factors of production; realization of households' and individuals' right to protection of their interests by the state. In fact, investment and innovation security is the provision of all economic agents with the necessary investment resources in order to fulfill their functions and realize their interests.

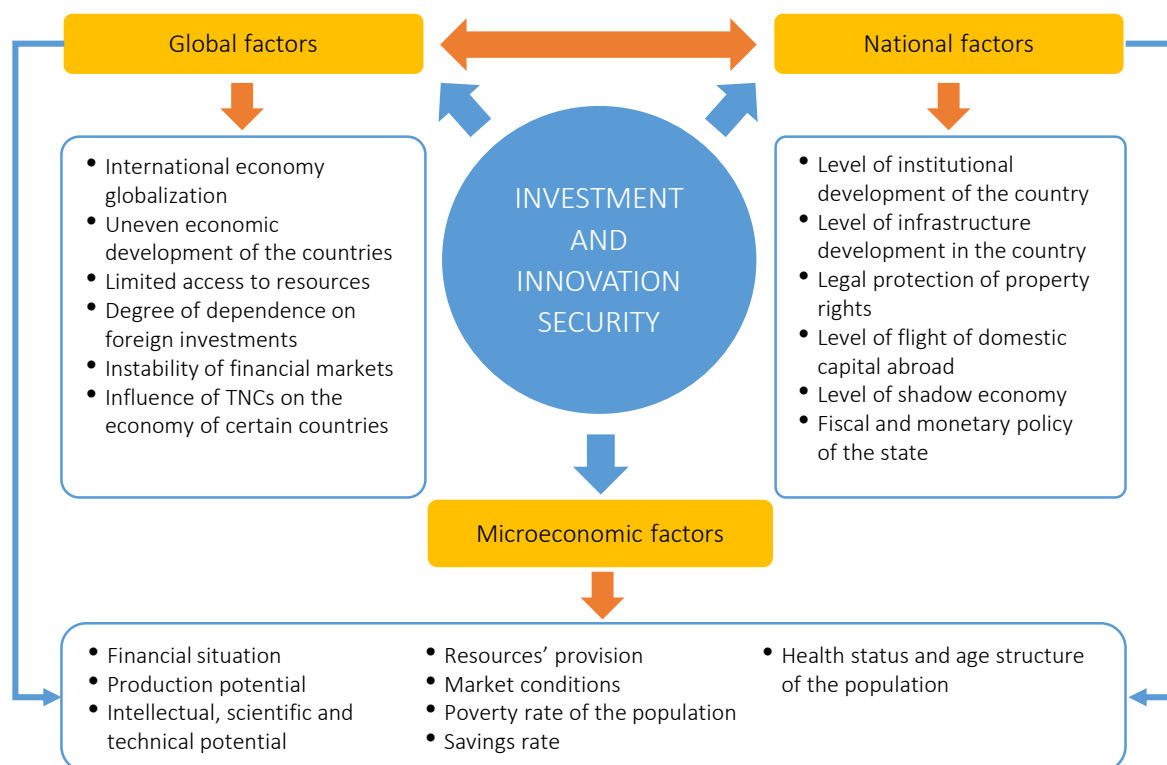
Since investment and innovation security is provided at different levels (see Figure 1), the factors affecting it are also diverse. The multiplicity of these factors can be traced using their classification according to the leveled approach: global, national and microeconomic factors of investment and innovation security.

The factors in each group may have different degrees of impact on the investment and innovation security, depending on the current economic situation, but in assessing the security level, their simultaneous impact should be taken into account (see Figure 2).

In turn, the presence of investment and innovation activities in the economy and the allocation of the appropriate category of economic security require the definition of its parameters and criteria. The negative influence of various factors may have different nature, for the identification of which it is necessary to form a system of indices of certain properties of investment and innovation processes, which state and dynamics characterizes national economic security.

The choice of certain indices and their groups for assessing threats is closely connected with the study of influence of such factors on the investment and innovation security, since the correct assessment of the level of factor influence on the state of the object serves as the basis for determining the level of danger and studying the possibilities of its prevention and liquidation.

Source: Compiled by the authors.



**Figure 2.** Investment and innovation security factors



Taking into account the systemic factors of investment and innovation security, the system of its indices should also be multi-leveled, that is to include groups of different types of indices. In the ideal scenario, it should be the integral index of national investment and innovation security, which gives its overall assessment, and a group of linear indices that assess the various types of threats.

The issue of criteria and indices of economic security remains controversial. There are different methods for assessing the economic security level of the national economy. They have no big differences, emphasizing the development of the integral index of economic security. However, understanding the complexity of assessing the economic security in general, the authors of all of these methods try to find the main indicators and indices that allow assessing the most important components of economic security.

In case of Ukraine, the main and most mentioned are two approaches to assessing the national economic security: National Methodology for Calculating the Level of Economic Security of Ukraine (Ministry of Economic Development and Trade of Ukraine (2013) and the approach of scientists of the National Institute for Strategic Studies (Kharazishvili & Sukhorukov, 2013). The main methodological difference in the introduced approaches is the selected indicators used to calculate integral index of economic security. These techniques can be used to determine the level of investment and innovation security (the first one contains a sub-index of investment and innovation security, the second one – a sub-index of investment and innovation security separately). The InVenture Investment Security Index (InVenture Investment Portal, 2018), characterizing the state of investment security of the country, takes a separate place. Its methodology is based on the assessment of 23 indices characterizing the investment activity, investment climate, current state of economic development, investment risks and investors' expectations.

At the same time, the necessary information about investment and innovation security can be obtained from international ratings, such as Economic Security Index (ESI), BERI index, Moody's and Standard & Poor's expert agencies,

ratings of highly reputed economic magazines "The Economist", "Euromoney", "Fortune", etc.

The international experience of national economic security assessment is based on a variety of approaches that include macroeconomic indicators and those characterizing the level of enterprises and households. For example, ESI, offered by Hacker et al. (2012), characterizes the security of certain individuals from the danger of economic losses (reducing their purchasing power) at the micro-level. It is calculated as the part of people who experience a reduction of more than 25% of their own income and cannot compensate it. This index includes three main constituents of unfavorable economic conditions: the probability of lowering incomes, increasing costs for medical care and the ability to compensate these economic shocks by spending their own savings.

The more detailed ESI by the International Labor Office is based on the same methodology with the expanded list of indicators and allows comparative estimates for different countries, which gives results, similar to the Index of Economic Well-Being. Methods of Bossert and D'Ambrosio (2013) and Rohde, Tang, and Prasada Rao (2014), are similar to the previous ones, but different in calculation. They are based on the micro-index use, which in the first case describes economic security as a risk of lack of savings to overcome economic shocks, while in the second case, the risk of financial losses, which at the same time reflects the level of households concern with regard to future financial capacity. The methodology of Rohde, Tang, and Prasada Rao (2014) is also based on the calculation of indicators' dispersion.

The Osberg and Sharpe (2014) index is based on the calculation of four macroeconomic indicators: unemployment, illness, widowhood and old age. In this case, the subjective risks of the financial standing weakening are based on objective macroeconomic data. This index is an integral part of the Index of Economic Well-Being (the IEWB Index of Economic Security).

Most of the above approaches to economic security assessment are characterized by the integral index use or the specific weight of individual indices, although there are also other approaches.

The main issues are discussed in order to select the necessary indicators for assessing the security level, which is acceptable in case of investment and innovation security. At the same time, in the methodology of Ukrainian (as well as, in general, Eastern European) and foreign researchers, there is a conceptual difference in the approaches to the choice of indicators of economic security assessment. Eastern European researches use macroeconomic indicators that characterize only the state of investment and innovation development of the economy, that is, the ability to develop and implement innovation and attract investment resources, and foreign researchers characterize the sufficiency of financial resources of households that determine the national economic security.

On the basis of consideration of existing possibilities of economic security indicators' systematization, it is possible to identify the main criteria on the basis of which its assessment in the investment and innovation sphere will be made.

The basic criterion should be the depth of the assessment period (short-term, medium-term and long-term), since the composition and structure of the risks and threats to investment and innovation security, as well as the degree of their manifestation, depend on it.

Thus, the investment and innovation activity varies over different periods of time, influencing inter alia the cyclical development of economy and manifesting itself in the dynamics of the investment market (recovery, growth, harvest and recession), which results in time-bound estimates.

The development potential of investment and innovation sphere, favorable business environment (investment climate), stability and independence of investment processes, their efficiency, as well as innovative development, should also be the separate criteria.

Besides, considering the above argumentation, it is advisable to take into account different influence of factors of the investment and innovation security.

Thus, the investment and innovation security can be assessed on the basis of use of the fol-

lowing blocks of indices: investment potential and investment activity indices, indices of innovation development at the national, corporate and household levels. Such system of indices reflects the state of investment and innovation processes at all stages of investment movement. Investment potential characterizes the possibility of necessary resources accumulation, the investment climate allows predicting the development of the situation, investment activity indices makes possible to carry out quantitative estimates of investments, and innovation development indices reflect the qualitative results of investments (see Table 2).

**Table 2.** System of investment and innovation security indices

Blocks of indices	Indices
National level	Capital investments
	Capital investments financed from the state and local budgets
	Direct foreign investment (equity)
	Expenditures for scientific and technical works
	GDP share of expenditures for research and development
Corporate level	Long-term financial investments of enterprises
	Capital assets and intangible assets (residual value)
	Coefficient of depreciation of fixed assets of enterprises
	Relative share of enterprises engaged in innovations
	Expenditures of enterprises for innovation activities
Household level	Average monthly salary of an employee
	Annual chain rates of real wage growth
	Share of the population below the poverty line
	Limit propensity to household consumption
	Limit propensity to household savings

Thus, the developed system of investment and innovation security indices of the national economy, consisting of three blocks (investment potential, investment activity, innovation development) at three levels of the economic system is aimed at reflecting its key characteristics in dynamics, namely stability, resistance, independence, as well as to become the basis for the development of current and promising means of economic policy aimed at ensuring the investment and innovation security of the national economy.



## 4. DISCUSSION

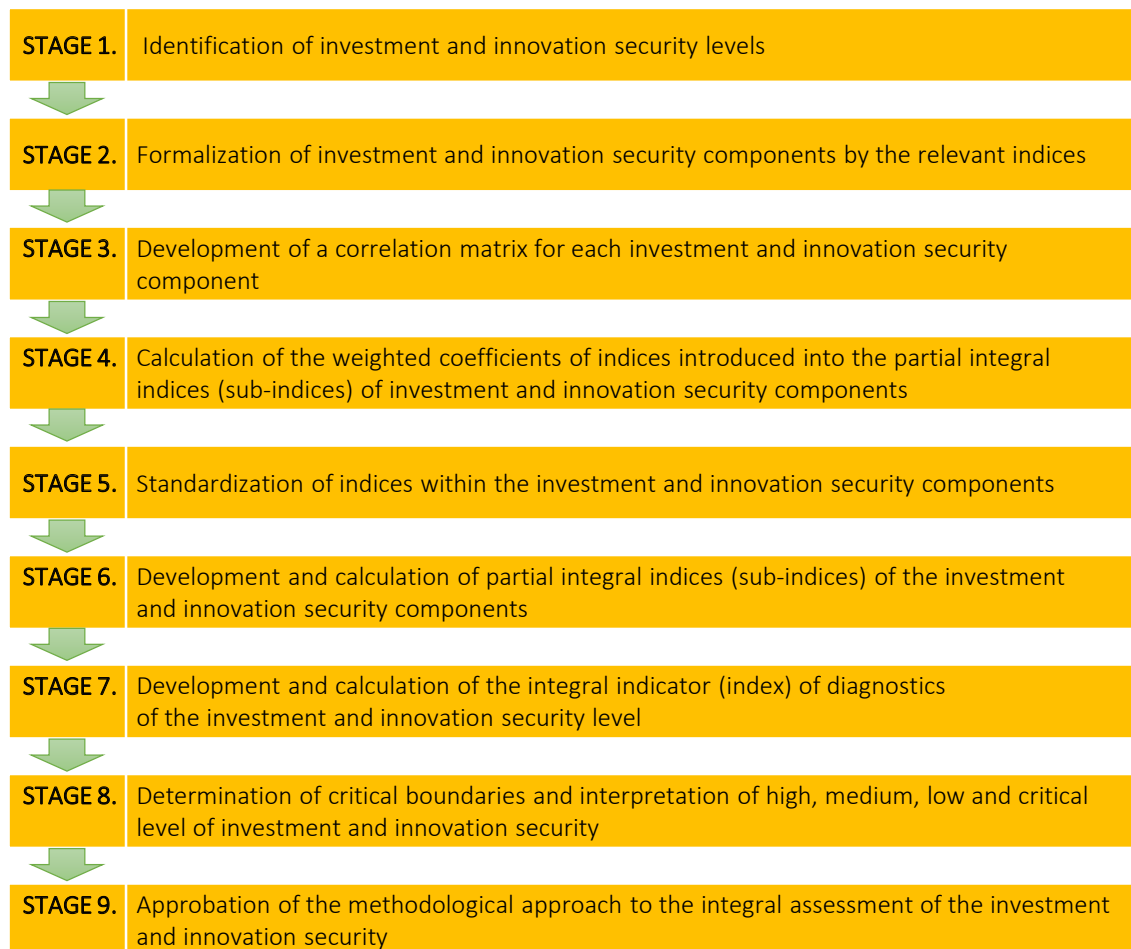
Based on foregoing in order to assess the level of investment and innovation security in dynamics, it is advisable to use the methodical apparatus of the integral estimations. The methodical approach to assessing the level of investment and innovation security can be presented as a set of stages that are consistently implemented (see Figure 3).

The proposed methodology allows us not only to comprehensively assess the investment and innovation security, but also to make a comparative analysis at the selected level with the further development of means that will allow solving the identified problems. The logical scheme of implementation of the methodological approach of integral assessment of the investment and innovation security level provides the implementa-

tion of 9 consecutive stages, which main source are official statistics of the State Statistics Service of Ukraine. The basis for the analysis of the innovative processes of official public data is substantiated in our previous studies (Biloshkurska et al., 2019; Biloshkurska, 2010; Omelyanenko et al., 2019).

During the analysis, appropriate calculations of the necessary single indices, sub-indices and a comprehensive integral index of investment and innovation security in Ukraine will be made. In addition, it is advisable to identify critical boundaries and to interpret the high, medium, low and critical level of investment and innovation security. The identification of investment and innovation security (stage 1) and the formalization of their components according to the relevant indices (stage 2) have already been implemented (see

Source: Compiled by authors in Ponomarenko et al. (2019).



**Figure 3.** Logical scheme of the methodical approach to the integral assessment of the investment and innovation security

**Table 3.** Dynamics of single indices of the investment and innovation security components in Ukraine (2008–2017)

Source: Compiled and calculated according to the data of the State Statistics Service of Ukraine (n.d.).

Index	Index value over the years									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
<b>Sub-index of the national investment and innovation security of Ukraine</b>										
1. Capital investment, billion UAH ( $X_1$ )	233.1	151.8	180.6	241.3	273.3	249.9	219.4	273.1	359.2	448.5
2. Capital investments financed from the state and local budgets, billion UAH ( $X_2$ )	21.49	10.85	15.95	25.12	24.84	12.97	8.66	21.18	36.08	56.87
3. Direct foreign investment (equity), billion USD ( $X_3$ )	35.62	38.99	45.37	48.2	51.71	53.7	38.36	32.12	31.23	31.61
4. Expenditures for scientific and technical works, billion UAH ( $X_4$ )	6.20	5.78	6.42	6.46	6.59	6.68	6.46	6.32	6.34	13.38
5. GDP share of expenditures for research and development, % ( $X_5$ )	0.86	0.91	0.88	0.77	0.77	0.77	0.69	0.63	0.48	0.45
<b>Sub-index of the corporate investment and innovation security of Ukraine</b>										
$w_1 = \frac{\sum_{j=1}^m  r_{x_1 x_j} }{\sum_{i=1}^n  r_{x_i x_j} }$										
1. Long-term financial investments of enterprises, billion UAH ( $X_6$ )	304.4	340.7	334.2	382.9	397.0	447.2	469.3	806.3	889.6	872.2
2. Capital assets and intangible assets (residual value), billion UAH ( $X_7$ )	970.2	1120.4	1184.8	1309.9	1687.1	1750.9	1781.5	2661.5	2771.6	2700.0
3. Coefficient of depreciation of fixed assets of enterprises, % ( $X_8$ )	66.4	65.9	80.5	81.2	80.2	81.7	86.5	63.3	61.3	58.4
4. Relative share of enterprises engaged in innovations, % ( $X_9$ )	13.0	12.8	13.8	16.2	17.4	16.8	16.1	17.3	18.9	16.2
5. Expenditures of enterprises for innovation activities, billion UAH ( $X_{10}$ )	12.0	7.9	8.0	14.3	11.5	9.6	7.7	13.8	23.2	9.1
<b>Sub-index of the households' investment and innovation security of Ukraine</b>										
1. Average monthly salary of an employee, UAH ( $X_{11}$ )	1,806	1,906	2,239	2,633	3,026	3,265	3,480	4,195	5,183	7,104
2. Annual chain rates of real wage growth, % ( $X_{12}$ )	106.3	90.8	110.2	108.7	114.4	108.2	93.5	79.8	109.0	119.1
3. Share of population below the poverty line, % ( $X_{13}$ )	7.1	5.8	8.8	7.8	9.1	8.4	8.6	6.4	3.8	2.4
4. Limit propensity to household consumption ( $X_{14}$ )	0.99	1.34	0.70	1.03	0.46	0.69	2.15	1.35	0.76	0.74
5. Limit propensity to household savings ( $X_{15}$ )	0.01	-0.34	0.30	-0.03	0.54	0.31	-1.15	-0.35	0.24	0.26

Note: \* Percentage of population with average per capita equivalent gross monthly income below a minimum subsistence income.

Figure 1 and Table 2). To implement the third stage, we provide the value of the single indices of the investment and innovation security components in Table 3.

Data given in Table 3 confirm the lack of a global investment and innovation security sub-index. It should be noted that the globalization component of investment and innovation security to an integral index that takes into account the impact of external factors is not included, as the global economy has its own developmental patterns, which requires a separate study. We are focusing on the country's domestic investment and innovation policy and its impact on economic security.

The logic of the calculation of the single indices weight: the module of the numerical value of the correlation coefficient reflects the degree (or measure) of the partial effect of one index on another. In such a case, the direction of indices change (inverse or direct) can be neglected; it is important to obtain all the paired correlation coefficients for each index, in order to estimate the researched index connection with others; in order to understand which of the indices is more important, one can compare the sum of the modules of the numerical values of the pair of correlation coefficients under the maximum criterion, that is, the dominant among the single indices is that one, using which the sum of the modules of numerical values of the pair correlation coefficients is greater.

Thus, by comparing the values of the pair correlation coefficients for the group of indices within the constituent of the favorable business environment, we can assume that the index with a higher value of the sum of modules of numerical values of the pair correlation coefficients  $\sum |r| \rightarrow \max$  is the dominant one, that is more important than others, and in the aggregate of indicators, its weight is higher. By this criterion, one can make a ranking of indices from the most to the least significant.

Following the offered logic, we can calculate the weighted coefficients  $w_i$  for each single index within the appropriate component of the business environment favorability. Thus, for the index  $X_1$  (capital investment) of the sub-index of the national investment and innovation security of Ukraine, the formula looks like:

$$w_1 = \frac{\sum_{j=1}^m |r_{x_1 x_j}|}{\sum_{i=1}^n |r_{x_i x_j}|}, \quad (1)$$

where  $r_{x_1 x_j}$  – is the paired correlation coefficients between the index  $X_1$  (capital investment) and the other  $j$ -th index;

for  $X_2$ :

$$w_2 = \frac{\sum_{j=1}^m |r_{x_2 x_j}|}{\sum_{i=1}^n |r_{x_i x_j}|} \quad (2)$$

and so on.

We will calculate the paired correlation coefficients of single indices being a part of sub-indices of investment and innovation security. The obtained data are given in Table 4.

Applying the formulae 1-3, the weighted coefficients for each investment and innovation security sub-index were obtained (Table 5).

Accordingly, each of the investment and innovation security sub-indices  $\hat{I}_{IIS}$  is calculated by the formula:

$$\hat{I}_{IIS} = w_1 Z_1 + w_2 Z_2 + \dots + w_j Z_j = \sum_{j=1}^m w_j Z_j, \quad (3)$$

where  $Z_1, Z_2, \dots, Z_j$  – the normalized single indices of the investment and innovation security sub-index,  $w_1, w_2, \dots, w_j$  – the weighted coefficients of the normalized single index  $i$ , upon that

**Table 4.** Matrix of the paired correlation coefficients of single indices of the investment and innovation security sub-indices

Source: Authors' calculations.

Index	Investment and innovation security sub-index				
Sub-index of the national investment and innovation security of Ukraine					
	$X_1$	$X_2$	$X_3$	$X_4$	$X_5$
$X_1$	1	–	–	–	–
$X_2$	0.927	1	–	–	–
$X_3$	–0.403	–0.458	1	–	–
$X_4$	0.785	0.828	–0.416	1	–
$X_5$	–0.913	–0.765	0.470	–0.621	1
Sub-index of corporate investment and innovation security of Ukraine					
	$X_6$	$X_7$	$X_8$	$X_9$	$X_{10}$
$X_6$	1	–	–	–	–
$X_7$	0.976	1	–	–	–
$X_8$	–0.649	–0.508	1	–	–
$X_9$	0.676	0.785	–0.022	1	–
$X_{10}$	0.529	0.486	–0.392	0.622	1
Sub-index of households' investment and innovation security of Ukraine					
	$X_{11}$	$X_{12}$	$X_{13}$	$X_{14}$	$X_{15}$
$X_{11}$	1	–	–	–	–
$X_{12}$	0.255	1	–	–	–
$X_{13}$	–0.749	–0.118	1	–	–
$X_{14}$	–0.133	–0.728	0.115	1	–
$X_{15}$	0.133	0.728	–0.115	–1.000	1

$$\sum_{j=1}^m w_j = 1. \quad (4)$$

**Table 5.** Coefficients of the weighted investment and innovation security sub-indices

Source: Authors' calculations.

Investment and innovation security sub-index	Weighted coefficients				
	$w_1$	$w_2$	$w_3$	$w_4$	$w_5$
National	0.230	0.226	0.133	0.201	0.210
Corporate	0.251	0.244	0.139	0.186	0.180
Household	0.156	0.225	0.135	0.242	0.242

After calculating the weighted coefficients of each investment and innovation security sub-index, it is necessary to standardize the single indices by identifying which of them are the stimulants (the index growth affects the growth of investment and

innovation security) and the disincentives (the index decrease affects the decrease of investment and innovation security). The formula for the standardization of the stimulant  $Z_{ij\uparrow}$  is as follows:

$$Z_{ij\uparrow} = \frac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}}. \quad (5)$$

The formula for standardization of the disincentive  $Z_{ij\downarrow}$  is as follows:

$$Z_{ij\downarrow} = \frac{X_{\max} - X_{ij}}{X_{\max} - X_{\min}}. \quad (6)$$

All standardized indices, both stimulants and disincentives, can acquire numerical values from 0 (minimum value) to 1 (maximum value).

We will compile a table of standardized values of single indices for the years 2008–2017 (Table 6).

**Table 6.** Standardized single indices of the investment and innovation security sub-indices in Ukraine (2008–2017)

Source: Authors' calculations.

Index	Index value over the years									
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
<b>Standardized indices of the sub-index of the national investment and innovation security of Ukraine</b>										
1. Capital investment ( $Z_{1\uparrow}^*$ )	0.274	0	0.097	0.302	0.410	0.331	0.228	0.409	0.699	1
2. Capital investments financed from the state and local budgets ( $Z_{2\uparrow}$ )	0.266	0.045	0.151	0.341	0.336	0.089	0	0.260	0.569	1
3. Direct foreign investment (equity) ( $Z_{3\uparrow}$ )	0.172	0.353	0.630	0.768	0.926	1.000	0.392	0.195	0.260	0
4. Expenditures for scientific and technical works ( $Z_{4\uparrow}$ )	0.055	0	0.084	0.089	0.107	0.118	0.089	0.071	0.074	1
5. GDP share of expenditures for research and development ( $Z_{5\uparrow}$ )	0.891	1	0.935	0.696	0.696	0.696	0.522	0.391	0.065	0
<b>Standardized indices of the sub-index of the corporate investment and innovation security of Ukraine</b>										
1. Long-term financial investments of enterprises ( $Z_{6\uparrow}$ )	0	0.062	0.051	0.134	0.158	0.244	0.282	0.858	1	0.970
2. Capital assets and intangible assets (residual value) ( $Z_{7\uparrow}$ )	0	0.083	0.119	0.189	0.398	0.433	0.450	0.939	1	0.960
3. Coefficient of depreciation of fixed assets of enterprises ( $Z_{8\downarrow}^{**}$ )	0.715	0.733	0.214	0.189	0.224	0.171	0	0.826	0.897	1
4. Relative share of enterprises engaged in innovations ( $Z_{9\uparrow}$ )	0.033	0	0.164	0.557	0.754	0.656	0.541	0.738	1	0.557
5. Expenditures of enterprises for innovation activities ( $Z_{10\uparrow}$ )	0.277	0.013	0.019	0.426	0.245	0.123	0	0.394	1	0.090
<b>Standardized indices of the sub-index of the households' investment and innovation security of Ukraine</b>										
1. Average monthly salary of an employee ( $Z_{11\uparrow}$ )	0	0.019	0.082	0.156	0.230	0.275	0.316	0.451	0.637	1
2. Annual chain rates of real wage growth ( $Z_{12\uparrow}$ )	0.674	0.280	0.774	0.735	0.880	0.723	0.349	0	0.743	1
3. Share of population below the poverty line* ( $Z_{13\downarrow}$ )	0.299	0.493	0.045	0.194	0	0.104	0.075	0.403	0.791	1
4. Limit propensity to household consumption ( $Z_{14\downarrow}$ )	0.686	0.479	0.858	0.663	1	0.864	0	0.473	0.822	0.834
5. Limit propensity to household savings ( $Z_{15\uparrow}$ )	0.686	0.479	0.858	0.663	1	0.864	0	0.473	0.822	0.834

Note: \*  $Z_{\uparrow}$  – the standardized indicator is a stimulant, \*\*  $Z_{\downarrow}$  – the standardized indicator is a disincentive.

**Table 7.** Equation of sub-indices of the investment and innovation security

Source: Compiled by the authors according to the data given in Tables 5 and 6.

Sub-index name	Sub-index equation
1. Sub-index of national investment and innovation security ( $\hat{I}_{NIS}$ )	$\hat{I}_{NIS} = 0.230Z_{1\uparrow} + 0.226Z_{2\uparrow} + 0.133Z_{3\uparrow} + 0.201Z_{4\uparrow} + 0.210Z_{5\uparrow}$
2. Sub-index of corporate investment and innovation security ( $\hat{I}_{CIS}$ )	$\hat{I}_{CIS} = 0.251Z_{6\uparrow} + 0.244Z_{7\uparrow} + 0.139Z_{8\downarrow} + 0.186Z_{9\uparrow} + 0.180Z_{10\uparrow}$
3. Sub-index of households' investment and innovation security ( $\hat{I}_{HIS}$ )	$\hat{I}_{HIS} = 0.156Z_{11\uparrow} + 0.225Z_{12\uparrow} + 0.135Z_{13\downarrow} + 0.242Z_{14\downarrow} + 0.242Z_{15\uparrow}$
4. Integral index of the investment and innovation security ( $I_{IS}$ )	$I_{IS} = \sqrt[3]{\hat{I}_{NIS} \cdot \hat{I}_{CIS} \cdot \hat{I}_{HIS}}$

The standardization of indices is made in order to reduce their numerical values to one unit of measurement, which greatly facilitates the development of the integral index. Thus, the integral index of the investment and innovation security  $I_{IS}$  can be calculated as the geometric mean of three sub-indices:

$$I_{IS} = \sqrt[3]{\hat{I}_{NIS} \cdot \hat{I}_{CIS} \cdot \hat{I}_{HIS}}, \quad (7)$$

where  $\hat{I}_{NIS}$  is a sub-index of national investment and innovation security,  $\hat{I}_{CIS}$  is a sub-index corporate investment and innovation security,  $\hat{I}_{HIS}$  is a sub-index of households' investment and innovation security (Ponomarenko et al., 2019).

As a result of calculations on the sixth and seventh stages of the methodological approach of the integrated assessment of the investment and innovation security, we have made Table 7.

Considering the consolidated data of the equations of partial integral indices (sub-indices) of the components of the business environment favorability and the complex integral indicator (index), given in Table 7, it should be noted that the integral index of the investment and innovation security is proposed as the geometric mean of 3 sub-indices (partial integral indicators), similar to the approach of Kyfiak (2016, p. 41). In our opinion, the main advantage of the statistical tool the "geometric mean" is the index limits  $I_{IS} \in [0;1]$ . Then, to implement the eighth stage of the methodological approach to the integral assessment of the investment and innovation security, it is necessary to determine the interval to split it into 4 assessment levels by the formula:

$$i = \frac{X_{\max} - X_{\min}}{n} = \frac{1-0}{4} = 0.25, \quad (8)$$

where  $i$  – the interval size,  $X_{\max}$  – the highest value of the sign,  $X_{\min}$  – the lowest value of the sign,  $n$  – number of groups.

After the calculations, we obtained the following assessment levels of investment and innovation security (see Table 8).

**Table 8.** Assessment levels of investment and innovation security

Integral index value	Characteristics of security level	Threats
$I_{IS} \in [0;0.25)$	Critical	Maximal
$I_{IS} \in [0.25;0.5)$	Low	Significant
$I_{IS} \in [0.5;0.75)$	Middle	Acceptable
$I_{IS} \in [0.75;1.0)$	High	Minimal

Thus, for the economic interpretation of the numerical value both as the sub-index of the corresponding component, and the integral index of the investment and innovation security, Table 8 shows the level division – from critical to high one. It is clear that the threats will be maximal at the critical level, and it will be minimal at a high level.

According to the calculations (see Table 6), using the equations given in Table 7, we will calculate the integral index of the investment and innova-



tion security of Ukraine and interpret and approbate one in the dynamics over the past 10 years in order to implement the last, ninth, stage of the proposed methodological approach (Table 9).

**Table 9.** Calculation of the integral index of the investment and innovation security of Ukraine (2008–2017)

Source: Authors' calculations.

Sub-index	Index value over the years										Changes (+/-) in 2017, compared to 2008
	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	
$\hat{I}_{NIIS}$	0.344	0.267	0.354	0.413	0.461	0.399	0.232	0.275	0.352	0.657	+0.313
$\hat{I}_{CIS}$	0.155	0.140	0.106	0.286	0.353	0.335	0.281	0.767	0.986	0.737	+0.581
$\hat{I}_{IISH}$	0.525	0.365	0.609	0.537	0.719	0.638	0.138	0.354	0.772	0.920	+0.395
$I_{IIS}$	0.304	0.239	0.283	0.399	0.489	0.440	0.208	0.421	0.645	0.764	+0.460

Data given in Table 9 show that during the period 2008–2017, the minimal – critical – level of investment and innovation security of Ukraine recorded in 2014 ( $I_{IIS} = 0.208$ ), and the maximum – high – level – in 2017 ( $I_{IIS} = 0.764$ ). At the same time, the state of innovation and investment security in Ukraine during the investigated period ranged from critical to high. However, in 2009 and 2014, we observe a critical level of investment and innovation security in Ukraine; in 2008, 2010–2013 and 2015 – the low; and in the 2016 – the average. During the period from 2008 to 2010, the Ukrainian enterprises mostly suffered from the global financial crisis, as the level of corporate investment and innovation security was critical. For households, the worst year was 2014, because only then the level of their investment and innovation security was critical. It is noteworthy that during the investigated period the critical and high levels of investment and innovation security for the macroeconomic security have not been recorded.

Thus, according to the methodical approach to the assessment of investment and innovation security of Ukraine, the integral index as the geometric mean of three sub-indices as the national security, corporate security and households' security was developed and tested. As a result, it was proved that in 2017, compared with 2008, the level of investment and innovation security of Ukraine has significantly increased from low to high, having fallen to a critical level due to the global financial crisis in 2009 and Russian aggression in 2014.

## CONCLUSION

It was determined that investment and innovation security involves protecting the interests of public institutions, providing it at global, national and regional levels, stimulating the production, distribution and consumption of goods and services produced by a national economy as a result of the interaction of factors of production, realization of households' and individuals' rights to protection of their interests by the state.

The system of investment and innovation security indices of the national economy has been compiled. It consists of three blocks (investment potential, investment activity, innovation development) at three levels of the economic system and reflects its key characteristics in dynamics, namely stability, resistance, independence. It should be the basis for the development of modern and promising means of economic policy aimed at ensuring the investment and innovation security of the national economy.

The proposed and approved methodological approach to assessing the investment and innovation security is an effective diagnostic tool at the macroeconomic and could be used as a base for sub-indexes), corporate and micro level of public administration. The results obtained during its development is the basis for finding effective ways of growth, forecasting trends and scenarios of further economic security development and ensuring the effectiveness of public administration in the conditions of environmental uncertainty and objective existence of threats.

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