4 INTEGRATED ASSESSMENT OF TECHNOLOGICAL DEVELOPMENT OF INDUSTRIAL PRODUCTION IN UKRAINE

4.1 Methodological support of the integrated assessment of industrial production technological development in Ukraine

In modern conditions the technological development of both industry as a whole and an industrial enterprise in particular becomes an important factor in the national security support. Positive dynamics of industry technological development provides the growth of the national security level and vice versa – the deterioration of national security is also due to the decline in technological development of industrial production. In order to develop the effective means to strengthen the national security of the state, it is necessary to study the dynamics of the industrial production technological development. In this regard there is a need for a comprehensive assessment of the technological development level of the largest industrial according to the industrial activity type.

The research works of many scientists are dedicated to the theoretical and applied aspects of production control at different levels. So, drawing on extensive original research, the book "Industrial technological development. A network approach" discusses the need for coordinating technical research and development with suppliers and customers and examines in detail how this should best be done (Hakansson, 2015). The book "Environmental policy and industrial innovation. strategies in Europe, the USA and Japan" concludes that innovation can be successfully harnessed by setting credible, long-term environmental goals and ensuring that regulatory instruments are grounded in flexibility, dialogue and trust (Wallace, 2017). The book "Technological collaboration in industry. Strategy, policy and internationalization in innovation" presents a synthesis of business functions and economic analysis and asks what the implications for skills development are; what effect public policy has; how far such ventures can go and what decision making processes are involved (Dodgson, 2018). The book "High technology industry and innovation Environments. The European experience" explores how new technologies, industrial innovation and the growth of high technology industry have affected regional employment and economic change in different European countries (Aydalot & Keeble, 2018). Recently, evolutionary theories of economic and technological change have attracted a considerable amount of attention which reflects the problems encountered by mainstream analysis of

dynamic phenomena and quantitative change. The book "Evolutionary theories of economic and technological change. Present status and future prospects" develops the debate and draws on the concepts of evolutionary biology, nonequilibrium thermodynamics, systems and organization theory (Saviotti & Metcalfe, 2018). However, the researchers didn't pay the appropriate attention to the problem of integrated assessment of technological development of industrial production.

In order to assess the follow-up level of technological development of industrial production, it is advisable to use the methodical apparatus of the integrated estimation. A methodical approach to assessing the level of industrial production technological development can be represented as a set of stages that are consistently implemented (Fig. 4.1).

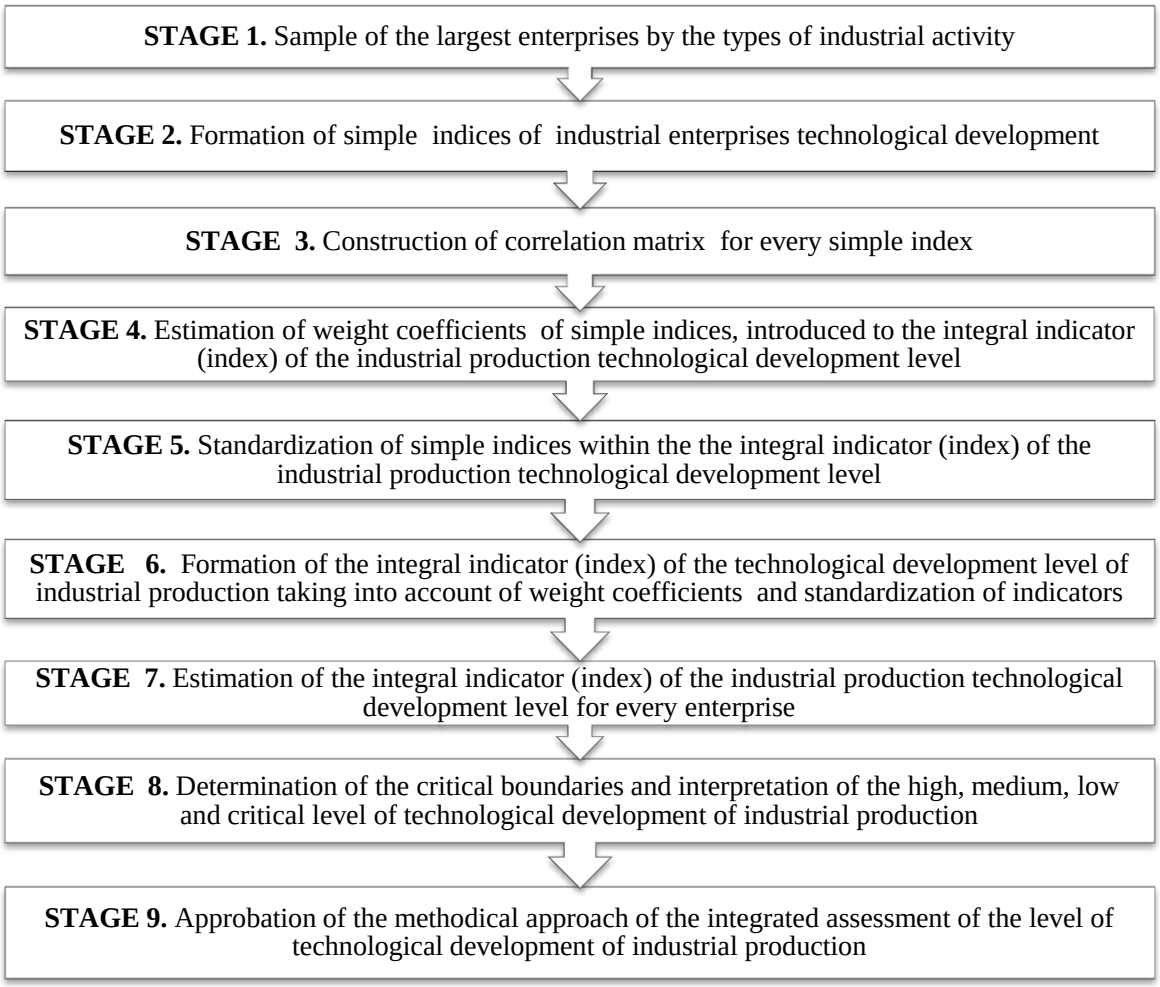

Fig. 4.1. **Logical scheme of the implementation of methodical approach to the integrated assessment of the industrial production technological development level**

Source: author's development

The use of the proposed methodological approach (Fig. 4.1) allows not only to comprehensively assess the level of technological development of the largest enterprises by the types of industrial activity, but also to conduct a comparative analysis with the further development of means that would solve the main problems of national security strengthening. The logical scheme of implementation of the methodological approach of integrated assessment of the industrial production technological development level involves the implementation of 9 consecutive stages, the main source of which are the public data of official statistics, available on the website of the State Statistics Service of Ukraine.

During the analysis, the appropriate calculations of the necessary simple indices will be made, according to which the complex integrated index of the industrial production technological development level will be formed. In addition, it is advisable to identify critical boundaries and interpret the high, medium, low and critical level of the technological development of industrial production.

A reliable integrated assessment of the level of technological development of industrial enterprises is possible only with due regard of a number of requirements: firstly, the methodological provision of such an assessment should be based on real (official) statistical data available in public access (Biloshkurskyi, 2013); and secondly, the study should cover a significant time lag of at least 10 years and reflect the dynamics (Biloshkurska & Biloshkurskyi, 2015); thirdly, the assessment object must simultaneously be the subject of the technological process (Biloshkurska, Biloshkurskyi & Omelyanenko, 2018).

The general integral indicator (index) of the level of technological development of industrial production (I_{ITD}) takes the form:

$$I_{ITD} = w_1 Z_1 + w_2 Z_2 + \cdots + w_j Z_j = \sum_{j=1}^{m} w_j Z_j, \qquad (4.1)$$

where Z_1, Z_2, …, Z_j are the standardized simple indices, introduced into the integral indicator (index) of the industrial production technological development level;

w_1, w_2, …, w_j are the weight coefficients of the *i-th* controlled simple index, in this regard:

$$\sum_{j=1}^{m} w_j = 1. \qquad (4.2)$$

The logic of the calculation of the simple indices weight is as follows:

− the numerical value module of the pair correlation coefficient reflects the degree (or measure) of the partial effect of one indicator on another, in such a case the direction of indicators changes (both inverse or direct) can be neglected;

− it is important to obtain all the coefficients of pair correlation for each indicator, in order to estimate the tightness of the researched indicator's connection with others;

− in order to understand which of the indicators is more important, we can compare the sum of the modules of the pair correlation coefficients numerical values by the maximum criterion, that is, the dominant in the aggregate of simple indices is that one, which sum of the modules of the pair correlation coefficients numerical values is higher, it will be the most important one (Biloshkurska, Biloshkurskyi & Slatvinskyi, 2018).

Thus, by comparing the values of the pair correlation coefficients for the simple indices of the integral indicator (index) of the level of technological development of industrial production, we can assume that the index with a higher value of the sum of numerical values modules of the pair correlation coefficients $\Sigma|r| \rightarrow \max$ is the dominant one, that is more important than others, and in the aggregate of indicators its weight is higher. Under this criterion one can conduct a ranking of indicators from the most to the least significant one.

Following the proposed logic, the weight coefficients (w_i) for each simple index are calculated within the integral indicator (index) of the technological development level of industrial production. Thus, for the index X_1 the formula takes the following form (Biloshkurska, Biloshkurskyi & Slatvinskyi, 2018):

$$w_1 = \sum_{j=1}^{m} \left| r_{x_1 x_j} \right| \Big/ \sum_{i=1}^{n} \left| r_{x_i x_j} \right|, \qquad (4.3)$$

where $r_{x_1 x_j}$ is a pair correlation coefficient between the index X_1 and other j-th index;

for X_2:

$$w_2 = \sum_{j=1}^{m} \left| r_{x_2 x_j} \right| \Big/ \sum_{i=1}^{n} \left| r_{x_i x_j} \right|. \quad (4.4)$$

And so on.

The standardization of indices is carried out by determining which of them is some incentive ones (the index increase affects the level of technological development) and the disincentive ones (the index decrease is positive). The formula for the incentive index ($Z_{ij\uparrow}$), is as follows:

$$Z_{ij\uparrow} = \frac{X_{ij} - X_{\min}}{X_{\max} - X_{\min}}. \quad (4.5)$$

The formula for the disincentive index ($Z_{ij\downarrow}$) is as such:

$$Z_{ij\downarrow} = \frac{X_{\max} - X_{ij}}{X_{\max} - X_{\min}}. \quad (4.6)$$

Then all the standardized indices, both incentive and disincentive ones, can acquire numerical values from 0 (minimum value) to 1 (maximum value).

Thus, the formulas (4.1)-(4.2) represent the form of connection of the integral indicator (index) of the level of technological development of industrial production, according to the formulas (4.3)-(4.4) the weight coefficients of simple indices are calculated, the formulas (4.5)-(4.6) formalize the standardization procedure.

The basic methodological framework for evaluating technological progress (development) are laid by such scientists as (Tinbergen, 1942), (Solow, 1957), (Moroney & Ferguson, 1970) and others. Ideas for the technological development assessment both of the national economy as a whole, and an enterprise in particular, have not lost their importance today. Technological progress is an objective factor in macroeconomic development on an innovation basis (Biloshkurska, Biloshkurskyi & Omelyanenko, 2018). Of course at the micro-level it is advisable to speak about the influence of technological progress on the efficiency of economic activity of the individual enterprise, and on its technological backwardness or high level of adaptability

to the economic conditions and technological capacity (Biloshkurska, 2015).

Compliance with all the requirements for the methodological support of the assessment of the technological development of industrial enterprises is provided by the following multiplicative dynamic model of the production function proposed by J. Tinbergen and R. Solow:

$$Q = A\, C^{\alpha} L^{\beta} e^{\gamma t}, \qquad (4.7)$$

where *Q* – quantity – is the result of the production and economic activity of the assessment object (volume of production or sale of industrial products (goods, works, services) in cash or in kind, or income from sales);

C – capital – factor of physical capital (the value of fixed assets or non-current assets, or total assets, etc.);

L – labor – labor factor or factor of human capital (average number of employees or annual salary fund, etc.)

parameter *A* is an absolute term (numeric value *Q*, if $\alpha = \beta = \gamma = 0$);

parameter α is the elasticity coefficient of the production volume by the physical capital factor (how many % will *Q* increase by the increase of C by 1%);

parameter β is the elasticity coefficient of the production volume by the labor factor (or the factor of human capital) (how many% *Q* will increase by *L* increase by 1%), and $\beta = 1 - \alpha$;

parameter γ is the parameter of technological progress or the elasticity coefficient of the production volume according to technological progress;

e is the Euler's number (the basis of the natural logarithm);

t is the factor of technological progress (year ordinal number) (Tinbergen, 1973; Solow, 1956).

In this regard the criterion of the effectiveness of technological development management is the conformity of the enterprise to the technological progress of the industry, which can be identified using the dynamic production function of Tinbergen-Solow.

A key component of the given dynamic model of the Tinbergen-Solow production function is the "technological progress parameter γ" which in our study will reflect the level of technological development of industrial production at the micro level. Thus, in the case of $\gamma > 0$, it is concluded that the technological development of the research object corresponds to the existing technological progress, since advanced modern technologies are

introduced into production, as well as the automated workplaces, logistic processes, which ultimately provides an additional increase of +γ% of output (or sales) of industrial products and the growing return on the scale of production. Then the technological progress parameter $\gamma > 0$ will act as an indicator of extended intensive reproduction. In the opposite case ($\gamma < 0$), the technological dynamics of the research object can be considered extensive, which corresponds to a simple reproduction, since the introduced innovation technologies in production are old-fashioned, "lagging" from the new ones, due to which the firm loses -γ% of output (or sales) of industrial products due to the descending return on the scale of production due to inconsistencies in technological progress.

Having written the formula (4.7) in a logarithmic form, taking into account the fact that $\beta = 1 - \alpha$, having carried out a number of algebraic transformations, in the form acceptable for the industrial production technological development modeling, the Tinbergen-Solow production function is written as follows (Biloshkurska, 2015):

$$\ln \mathrm{Q} - \ln \mathrm{L} = \ln \mathrm{A} + \alpha\,(\ln \mathrm{C} - \ln \mathrm{L}) + \gamma \mathrm{t}. \qquad (4.8)$$

Thus, the first simple index to be introduced to the integral indicator (index) of the technological development level of industrial production is the technological progress parameter γ, the key parameter of the Tinbergen-Solow function. This indicator is an incentive one.

The second index, reflecting the proportionality of the main resources use in the industrial production – physical and human capital – is proposed to be the Marginal rate of technical substitution (*MRTS*):

$$MRTS = \frac{MP_L}{MP_C} = -\frac{\alpha L}{\beta C}, \qquad (4.9)$$

where MP_{L} is the marginal product of labor – how many units Q changes when L 1 unit increases;

MP_{C} is the marginal product of capital – how many units Q changes when C 1 unit increases;

Formula (4.9) represents the expenditure of human capital to compensate the reduction of 1 unit of physical capital, and the value $MRTS < -1$ indicates the predominance of the physical capital factor over human capital in the

structure of productive resources, and *MRTS* > -1 – the prevailing significance of the labor factor or human capital factor. For industrial production, where the factor of capital is the key one, *MRTS* in the integral indicator plays the role of a disincentive index.

The third index to be introduced to the integral indicator (index) of the technological development level of industrial production is the Ratio of Intangible Assets to Total Assets (*RIA*):

$$RIA = \frac{IA}{TA} \cdot 100\%, \tag{4.10}$$

where *IA* is the book value of intangible assets;

TA is the total assets volume.

The index Ratio of intangible assets to total assets, formula (4.10), shows the share of the value of intangible assets in the enterprise balance, is an incentive index.

The fourth simple index to be introduced to the integral indicator (index) of the technological development level of industrial production, is called the Fixed Asset Renewal Index (*FAR*), and is calculated as follows:

$$FAR = \frac{OV_1 - OV_0}{OV_1} \cdot 100\%, \tag{4.11}$$

where OV_0 and OV_1 is the original value of fixed assets as at the beginning of year and as of the year-end respectively.

The Fixed Asset Renewal Index, formula (4.11), which shows, how much interest the fixed assets have been updated during the current year, is an incentive index.

The last fifth index that will be introduced to the integral indicator (index) of the technological development level of industrial production, will be the Wear and Tear of Fixed Assets Coefficient (*WTC*):

$$WTC = \frac{WT_{FA}}{OV}, \tag{4.12}$$

where WT_{FA} is a wear and tear of fixed assets.

The Wear and Tear of Fixed Assets Coefficient, formula (4.12), showing

the part of wear and tear cost of the fixed assets, is a disincentive index.

So, taking into account the symbols, given in formulas (4.7)-(4.12), the integral indicator (index) of the level of technological development of industrial production (I_{ITD}) takes the following final form:

$$I_{ITD} = w_1 Z_{\gamma\uparrow} + w_2 Z_{MRTS\downarrow} + w_3 Z_{RIA\uparrow} + w_4 Z_{FAR\uparrow} + w_5 Z_{WTC\downarrow}. \quad (4.13)$$

Thus, after studying the main provisions of the methodological support of the integrated assessment of the technological development of industrial production, let's come down to the practical part of the implementation of the proposed methodological approach (see Fig. 1), which will result in ranking of the largest industrial enterprises of Ukraine according to the industrial activity types.

4.2 Analysis of technological dynamics of the largest industrial enterprises of Ukraine by types of industrial activity

To carry out an integrated assessment of the level of technological development of industrial production in Ukraine it is advisable first of all simulate the Tinbergen-Solow production function in the largest enterprises chosen by types of industrial activity. As a result of simulation, the technological progress parameter will be obtained and the marginal rate of technical substitution will be calculated. For the calculation of the remaining indices, the output data will be generated additionally.

The results of a sample of the largest domestic enterprises by types of industrial activities participating in the innovation process, are given in Table 4.1.

Let's proceed to the formation of the basic data for the Tinbergen-Solow production function simulation by means of MS Excel and the calculation of simple indices that will be introduced into the integral indicator (index) of the industrial production technological development level. The first enterprise in the Table 1 is the JSC "Ukrnafta". After transforming the absolute indices into logarithms, we made the calculation table 4.2.

Table 4.1

Sample of enterprises by types of industrial activities engaged in innovation activities

Name of the type of industrial activity for the CCEA-2010	Enterprise	USREOU code	Period, years
1. Extraction of crude oil and natural gas	PJSC "Ukrnafta"	00135390	2002-2016
2. Extraction of stone and brown coal	PrJSC "DTEK Pavlogradugol"	00178353	2004-2016
3. Production of food products	PJSC "Myronivsky Hliboproduct"	25412361	2002-2016
4. Manufacture of beverages	PrJSC "Kalsberg Ukraine"	00377511	2002-2016
5. Manufacture of tobacco products	PrJSC "Imperial Tobacco Production Ukraine"	20043260	2004-2016
6. Manufacture of chemicals and chemical products	PJSC "DniproAzot"	05761620	2002-2016
7. Production of basic pharmaceuticals	PJSC "Kyivmedpreparat"	00480862	2002-2016
8. Metallurgical production	PJSC "Southern mining and processing plant"	00191000	2002-2016
9. Machine-building, except for repair and installation of machinery and equipment	PJSC "Motor Sich"	14307794	2002-2016
10. Production, transmission and distribution of electricity	PJSC "DTEK Dniproenergo"	00130872	2002-2016

Source: formed according to the data available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA)

Table 4.2

Basic data for the Tinbergen-Solow production function simulation PJSC "Ukrnafta"

Years	Q*, thous. UAH	C**, thous. UAH	L***, people	ln Q	ln C	ln L	ln Q – ln L	ln C– ln L	t
2002	2047490	4985160	25624	14.5321	15.4220	10.1513	4.3808	5.2707	1
2003	2954480	6265020	20126	14.8988	15.6505	9.9098	4.9891	5.7407	2
2004	4362132	8187646	20192	15.2885	15.9181	9.9130	5.3754	6.0051	3
2005	5575256	8056200	28628	15.5338	15.9020	10.2621	5.2717	5.6398	4
2006	8379082	9394251	30759	15.9412	16.0556	10.3339	5.6073	5.7217	5
2007	4929138	10528518	31490	15.4107	16.1696	10.3574	5.0532	5.8122	6
2008	9400465	12935761	30847	16.0563	16.3755	10.3368	5.7195	6.0387	7
2009	9978912	18883008	29697	16.1160	16.7538	10.2988	5.8172	6.4550	8
2010	20010407	18425293	29204	16.8118	16.7292	10.2821	6.5297	6.4472	9
2011	12968215	31398561	28821	16.3780	17.2623	10.2689	6.1092	6.9934	10
2012	15009729	32573402	27908	16.5242	17.2990	10.2367	6.2875	7.0623	11
2013	21101331	28241427	26767	16.8648	17.1563	10.1949	6.6699	6.9614	12
2014	27891932	33207519	26392	17.1438	17.3183	10.1808	6.9630	7.1375	13
2015	28761995	35182434	26120	17.1746	17.3761	10.1705	7.0041	7.2056	14
2016	22578750	33249809	25117	16.9325	17.3196	10.1313	6.8012	7.1883	15

* Q – annual amount of net income from the sales of products, thousand UAH;

** C – capital – annual amount of total assets, thousand UAH;

*** L – labor – the average number of employees, persons.

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

To obtain the regression (elasticity) coefficients of the production function, we use in the MS Excel environment the "Data Analysis" add-on, in which we select the "Regression" option. "Input interval Y" forms a table row (ln Q – ln L), "Input interval X" forms the rows (ln C – ln L) and t.

The results of the correlation-regression analysis, obtained using MS Excel, are shown in Fig. 4.2.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,951177681**							
R-squared	**0,90473898**							
Normalized R-squared	0,888862144							
Standard Error	0,267201082							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	8,137026836	4,068513418	**56,98483909**	7,47294E-07	**10,67565821**		
Balance	12	0,856757022	0,071396418					
Total	14	8,993783858						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	2,755057978	1,815936179	1,517155729	0,155121473	-1,201527067	6,711643022	-1,201527067	6,711643022
α	**0,342231695**	0,345634018	0,990156284	0,341643591	-0,410840138	1,095303529	-0,410840138	1,095303529
γ	**0,120904322**	0,051839337	2,332289125	0,03791261	0,007956109	0,233852535	0,007956109	0,233852535
A	**15,7219524**							
β	**0,657768305**							

Fig. 4.2. **Results of Tinbergen-Solow production function simulation PJSC "Ukrnafta"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

From the data shown in Fig. 4.2, it is evident that the equation of Tinbergen-Solow production function, developed for PJSC "Ukrnafta", is characterized by high values of the statistical correlation and determination coefficients. So, the multiple correlation coefficient R is 0.951, which indicates a very tight relationship between income, total assets, average number of employees and technological progress. The reliability of the correlation coefficient confirms the high value of the t-test 10.66 (the critical value is 1.782 with a significance level of α = 0.05 and k = 12 freeness). The multiple determination coefficient R^2 was 0.905 and proves that the variation of income by 90.5% is due to the variation of the production function factors. The reliability of the determination coefficient confirms the high value of the F-test 56.98 under the critical 3.89 (with a significance level of α = 0.05 and k_1= 2, k_2 = 12 freeness).

Analysis of the production function parameters of PJSC "Ukrnafta", given in Fig. 4.2 shows that in case of total assets increase (α) by 1%, the

income growth is reached by 0.34%; an increase in the average number of employees (β) by 1% leads to an increase in the elasticity of production by the labor factor by 0.66%. At the same time, the labor factor prevails in the structure of production factors, since it has a greater impact on the result. It should also be noted: the additional income of the enterprise, obtained as a result of its compliance with technological progress, amounted to 0.13% of revenue ($e^{0.12} - 1 = 0.13$), indicating a high level of innovation development.

According to the data given in Fig. 4.2, using formula (4.10), calculations were made, according to which *MRTS* = -0.520 for PJSC "Ukrnafta". The obtained Marginal rate of technical substitution confirms the twice as high meaning of the labor factor (human capital), as compared to the physical capital factor, the low level of mechanization and automation of modern industrial production means that saving (dismissing) of 1 thousand employed persons of PJSC "Ukrnafta" can compensate 1.92 million UAH of total assets.

The remaining indices are calculated using formulas (4.11)-(4.13). As a result of calculations, we form the Table 4.3.

Table 4.3

The meaning of such indices as Ratio of intangible assets to total assets, Fixed asset renewal and Wear and tear of fixed assets coefficient for PJSC "Ukrnafta"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.275	0.098	0.522
2003	0.319	0.059	0.551
2004	0.264	0.229	0.480
2005	0.270	0.136	0.468
2006	0.270	0.122	0.463
2007	0.328	0.071	0.485
2008	0.291	0.056	0.509
2009	0.242	0.056	0.528
2010	0.304	0.045	0.546
2011	0.214	0.328	0.146
2012	0.237	0.015	0.239
2013	0.328	-0.360	0.078
2014	0.306	0.043	0.194
2015	0.299	-0.115	0.078
2016	0.341	0.029	0.066
On the verage	**0.286**	**0.054**	**0.357**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

From the data given in Table 4.3, can be seeing that during the investigated period the share of intangible assets in total assets of PJSC "Ukrnafta" at the end of 2016 increased by 0.066%, reaching the maximum value of 0.341%. The fixed assets of the enterprise on average updated by 5.4% for 2002-2016, with the highest annual update level of 32.8% was recorded in 2011, resulting in a 40% decrease in the wear and tear ratio. During the researched period the wear and tear ratio of fixed assets of PJSC "Ukrnafta" decreased by 45.6%, reaching its minimum of 6.6% at the end of 2016. It is also worth noting that for the formation of the integral indicator (index) of the level of technological development of industrial production in Ukraine the average value of the indices given in Table 4.4, for the years 2002-2017 will be taken.

Similarly, we carry out calculations for the remaining enterprises, the results of which are contained in the annexes. The data given in the annexes, Fig. 4.2 and Table 4.3, are summarized in Table 4.4.

Table 4.4

Summarized data of the average values of simple indices of the technological development of the largest industrial enterprises of Ukraine for 2002-2016.

Enterprise	Technological progress parameter (γ)	Marginal rate of technical substitution (*MRTS*)	Ratio of intangible assets to total assets (*RIA*), %	Fixed asset renewal (*FAR*)	Wear and tear of fixed assets coefficient (*WTC*)
PJSC "Ukrnafta"	0.121	-0.520	0.286	0.054	0.357
PrJSC "DTEK Pavlogradugol"	0.215	-0.235	0.317	0.213	0.295
PJSC "Myronivsky Hliboproduct"	-0.074	-18.296	0.812	0.842	0.176
PrJSC "Kalsberg Ukraine"	0.102	-1.309	1.316	0.240	0.376
PrJSC "Imperial Tobacco Production Ukraine"	-0.001	-1.077	0.265	0.143	0.401
PJSC "DniproAzot"	0.160	-0.378	0.235	0.023	0.651
PJSC "Kyivmedpreparat"	0.142	-0.231	0.537	0.174	0.448
PJSC "Southern mining and processing plant"	0.155	-0.558	0.057	0.131	0.408
PJSC "Motor Sich"	0.009	-33.313	0.350	0.195	0.465
PJSC "DTEK Dniproenergo"	0.173	-0.299	0.246	0.105	0.574
max	0.215	-0.231	1.316	0.842	0.651
min	-0.074	-33.313	0.057	0.023	0.176

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Data, given in Table 4.4 show that the first index, in the case of $\gamma > 0$, reflects the enterprise correspondence with the technological progress (typical for all sample enterprises, except PJSC "Myronivsky Hliboproduct" and PrJSC "Imperial Tobacco Production Ukraine") and, accordingly, the satisfactory level of technological development. Marginal rate of technical substitution reflects the human capital expenditures to compensate the reduction of 1 million USD of physical capital, and the value $MRTS < -1$ indicates the predominance of the physical capital factor over the human capital in the structure of productive resources (typical for the PJSC "Myronivsky Hliboproduct", PrJSC "KalsbergUkraine", PrJSC "Imperial Tobacco Production Ukraine" and PJSC "MotorSich") and the value $MRTS > -1$ proves the significance of the labor factor or human capital factor (typical for PJSC "Ukrnafta", PrJSC "DTEKPavlogradugol", PJSC "DniproAzot", PJSC "Kyivmedpreparat", PJSC "Southern mining and processing plant" and PJSC "DTEKDniproenergo"). The largest annual weight of intangible assets in total assets was at the PrJSC "Kalsberg Ukraine" (1.32%), and the lowest one at the PJSC "Southern mining and processing plant" (0.06%). During 2002-2016 in PJSC "Myronivsky Hliboproduct", the fixed assets were renewed up to 84.2%, which reduced their wear and tear to 17.6%. This is the best result among the sample companies. The worst result was recorded in the technological development of PJSC "DniproAzot" – the renovation of fixed assets by only 2.3% and wear and tear by 65.1% respectively.

So, during the analysis of the technological dynamics of the largest industrial enterprises of Ukraine by types of industrial activity, it was possible to calculate and track the dynamics of key simple indices of their technological development. This allowed forming the prerequisites for the formation and approbation of the integral indicator (index) of the industrial production technological development level in Ukraine.

4.3 Formation and approbation of the integral index of the industrial production technological development in Ukraine

We will begin with the integrated assessment of the favorable business environment by constructing the correlation matrix of simple indices of technological development of the largest industrial enterprises in Ukraine, laid into the methodology for calculation of weigh coefficients (see formulas (4.3)-(4.4). The correlation matrix is constructed using the MS Excel add in "Data Analysis", function "Correlation". As a result, we get Table 4.5.

Table 4.5

Correlation matrix of simple indices of the integral indicator (index) of technological development level of industrial production in Ukraine

	γ	*MRTS*	*RIA*	*FAR*	*WTC*
γ	1				
MRTS	0.669	1			
RIA	-0.321	-0.113	1		
FAR	-0.675	-0.457	0.500	1	
WTC	0.452	0.200	-0.394	-0.734	1

From the data, given in Table 4.5, it is evident that the closest correlation between five simple indices of technological development of the largest Ukrainian industrial enterprises is between the Fixed asset renewal and Wear and tear of fixed assets coefficient ($r_{FAR.WTC} = -0.734$). At the same time the lowest correlation is between the marginal rate of technical substitution and the ratio of intangible assets to total assets ($r_{MRTS.RIA} = -0.113$).

In order to simplify the calculation of weight coefficients of simple indices the calculation Table 4.6 was made.

As can be seen from the Table 4.6, the most significant simple index in the integral indicator (index) of the technological development level of industrial production was the fourth one, namely Fixed asset renewal ($w_4 = 0.262$), and the least important occurred to be the Ratio of intangible assets to total assets ($w_3 = 0.148$) (see note to Table 4.6). The sum of weight coefficients of 5 simple indices was 1, therefore the conducted calculations are correct and will be used in the formation of the integral indicator (index) of the level of technological development of industrial production in Ukraine. Then the equation of the integral indicator (index) of the level of technological

development of industrial production in Ukraine (I_{ITD}) takes the form of:

Table 4.6

Table for calculating the weight coefficients of the integral indicator (index) of technological development level of industrial production in Ukraine

$\left\|r_{x_1x_j}\right\|$	$\left\|r_{x_2x_j}\right\|$	$\left\|r_{x_3x_j}\right\|$	$\left\|r_{x_4x_j}\right\|$	$\left\|r_{x_5x_j}\right\|$	Total
0.669	0.669	0.321	0.675	0.452	x
0.321	0.113	0.113	0.457	0.200	x
0.675	0.457	0.500	0.500	0.394	x
0.452	0.200	0.394	0.734	0.734	x
0.669	0.669	0.321	0.675	0.452	x
$\sum_{j=1}^{m}\left\|r_{x_1x_j}\right\|$	$\sum_{j=1}^{m}\left\|r_{x_2x_j}\right\|$	$\sum_{j=1}^{m}\left\|r_{x_3x_j}\right\|$	$\sum_{j=1}^{m}\left\|r_{x_4x_j}\right\|$	$\sum_{j=1}^{m}\left\|r_{x_5x_j}\right\|$	$\sum_{j=1}^{m}\left\|r_{x_ix_j}\right\|$
2.118	1.439	1.329	2.366	1.780	9.032
w_1 = 0.234	**w_2 = 0.159**	**w_3 = 0.148**	**w_4 = 0.262**	**w_5 = 0.197**	**$\sum w_j$ = 1**

Source: author's calculations.

Note: X_1 – Technological Progress Parameter (γ); X_2 – Marginal Rate of Technical Substitution (*MRTS*); X_3 – Ratio of Intangible Assets to Total Assets (*RIA*); X_4 – Fixed Asset Renewal (*FAR*); X_5 – Wear and Tear of Fixed Assets Coefficient (*WTC*).

$$I_{ITD} = 0.234Z_{\gamma\uparrow} + 0.159Z_{MRTS\downarrow} + 0.148Z_{RIA\uparrow} + 0.262Z_{FAR\uparrow} + 0.197Z_{WTC\downarrow}. \quad (4.14)$$

Let's determine the interval size to break the levels of technological development of industrial production into 4 groups according to the formula:

$$i = \frac{X_{max} - X_{min}}{n} = \frac{1 - 0}{4} = 0.25, \quad (4.15)$$

where i is the interval size;

X_{max} is the maximum characteristic value;

X_{min} – the minimum characteristic value;

n is the number of groups.

Having made the calculations, we obtain the following levels of technological development of industrial production (Table 4.7).

Table 4.7

Levels of technological development of industrial production

Integral index value	Assessment of the technological development level	Extended reproduction ability
$I_{ITD} \in [0; 0.25)$	critical	absent
$I_{ITD} \in [0.25; 0.5)$	low	partial
$I_{ITD} \in [0.5; 0.75)$	medium	satisfactory
$I_{ITD} \in [0.75; 1.0]$	high	complete

Source: author's development

Thus, for the economic interpretation of the numerical value of the integral indicator (index) of the technological development level of industrial production in Ukraine, the division at the levels, from critical to high one, is given in Table 4.7. It is clear that at the critical level of technological development the enterprise will be unable to expand the reproduction, and at a high level it will have all the necessary prerequisites for expanded reproduction.

We will conduct a ranking of the investigated enterprises under the value of the integral indicator (index) of the level of technological development of industrial production in Ukraine, taking into account the formula (4.15) and standardized simple indices (Table 4.8).

Table 4.8

Ranking of the largest enterprises under the value of the integral indicator (index) of the level of technological development of industrial production in Ukraine

Enterprise	$Z_{\gamma\uparrow}$	$Z_{MRTS\downarrow}$	$Z_{RIA\uparrow}$	$Z_{FAR\uparrow}$	$Z_{WTC\downarrow}$	$\boldsymbol{I_{ITD}}$	Rank	Development level
PJSC "Ukrnafta"	0.675	0.009	0.182	0.038	0.619	**0.318**	7	low
PrJSC "DTEK Pavlogradugol"	1	0.0001	0.207	0.232	0.749	**0.473**	3	low
PJSC "Myronivsky Hliboproduct"	0	0.546	0.600	1	1	**0.634**	1	medium
PrJSC "Kalsberg Ukraine"	0.609	0.033	1	0.265	0.579	**0.479**	2	low
PrJSC "Imperial Tobacco Production Ukraine"	0.253	0.026	0.165	0.147	0.526	**0.230**	9	critical
PJSC "DniproAzot"	0.810	0.004	0.141	0	0	**0.211**	10	critical
PJSC "Kyivmedpreparat"	0.747	0	0.381	0.184	0.427	**0.364**	5	low
PJSC "Southern mining and processing plant"	0.792	0.010	0	0.132	0.512	**0.323**	6	low
PJSC "Motor Sich"	0.287	1	0.233	0.210	0.392	**0.393**	4	low
PJSC "DTEK Dniproenergo"	0.855	0.002	0.150	0.100	0.162	**0.281**	8	low

Note: $Z_{\uparrow}$is a standardized incentive index, $Z_{\downarrow}$ is a standardized disincentive index
Source: author's calculations.

Data, given in Table 4.8, show that among the researched large industrial enterprises, two of them, namely PrJSC "Imperial Tobacco Production Ukraine" (I_{ITD} = 0.23) and PJSC "DniproAzot" have the lowest level, corresponding to the critical technological development. Only the PJSC "Myronivsky Hliboproduct" has the average level of technological development (I_{ITD} = 0.634). The development level of other enterprises is low, and they are only partially capable of expanded reproduction.

Thus, during the implementation of the methodical approach to the integrated assessment of the level of technological development of industrial production, an integral indicator (index) was formed, which included 5 coefficients: Technological Progress Parameter, Marginal Rate of Technical Substitution, Ratio of Intangible Assets to Total Assets; Fixed Asset Renewal & Wear and Tear of Fixed Assets Coefficient. As a result, the ranking of 10 largest domestic enterprises, chosen by types of industrial activity, was conducted, based on the values of the integral indicator (index) of the level of technological development of industrial production in Ukraine and the developed criteria. The results obtained during its development lay the foundations for finding effective ways of technological development and expanded reproduction of industrial activity entities, forecasting of tendencies and development of scenarios for further development of industry, as well as increase of its efficiency in conditions of environmental uncertainty.

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Appendix A

Basic data for the Tinbergen-Solow production function simulation

Table A.1

PrJSC "DTEK Pavlogradugol"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2004	1296038	3084290	28830	14.0748	14.9418	10.2692	3.8057	4.6727	1
2005	1596226	3258613	36555	14.2832	14.9968	10.5066	3.7766	4.4902	2
2006	2222160	2676504	34323	14.6140	14.8000	10.4436	4.1704	4.3565	3
2007	2435582	3775492	30654	14.7057	15.1440	10.3305	4.3752	4.8135	4
2008	3551538	4533313	28307	15.0829	15.3270	10.2509	4.8320	5.0761	5
2009	3273453	6044204	25948	15.0014	15.6146	10.1638	4.8375	5.4508	6
2010	4616481	8843716	25026	15.3451	15.9952	10.1277	5.2175	5.8675	7
2011	5735725	8906266	25515	15.5622	16.0023	10.1470	5.4152	5.8552	8
2012	7865983	9010411	25661	15.8781	16.0139	10.1527	5.7253	5.8612	9
2013	8853858	9423832	25657	15.9964	16.0588	10.1526	5.8438	5.9062	10
2014	11943718	13789586	24852	16.2957	16.4394	10.1207	6.1750	6.3187	11
2015	18105310	20920328	24255	16.7117	16.8562	10.0964	6.6153	6.7599	12
2016	19689599	24412254	24026	16.7956	17.0106	10.0869	6.7087	6.9237	13

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.2

PJSC "Myronivsky Hliboproduct"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	420215	242390	221	12.9485	12.3983	5.3982	7.5504	7.0001	1
2003	629879	730132	271	13.3533	13.5010	5.6021	7.7512	7.8989	2
2004	1344590	1193060	2990	14.1116	13.9920	8.0030	6.1086	5.9890	3
2005	1705814	2075455	7121	14.3496	14.5457	8.8708	5.4787	5.6749	4
2006	1739031	4190193	14987	14.3688	15.2483	9.6149	4.7539	5.6333	5
2007	2456936	4781301	436	14.7144	15.3802	6.0776	8.6368	9.3026	6
2008	4233218	7359775	550	15.2585	15.8115	6.3099	8.9486	9.5016	7
2009	5825262	8882118	2872	15.5777	15.9996	7.9628	7.6150	8.0368	8
2010	7719355	12291223	22766	15.8592	16.3244	10.0330	5.8262	6.2914	9
2011	9964494	15474852	24779	16.1145	16.5547	10.1178	5.9968	6.4370	10
2012	11381573	19815308	27800	16.2475	16.8020	10.2328	6.0147	6.5692	11
2013	11826711	21343589	30200	16.2859	16.8763	10.3156	5.9703	6.5607	12
2014	14636689	33411357	29923	16.4990	17.3244	10.3064	6.1927	7.0180	13
2015	10762742	26672302	30979	16.1916	17.0991	10.3411	5.8505	6.7581	14
2016	12724865	40718494	3225	16.3591	17.5222	8.0787	8.2804	9.4435	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.3

PrJSC "Kalsberg Ukraine"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	370467	283900	2741	12.8225	12.5564	7.9161	4.9064	4.6403	1
2003	377350	541263	2834	12.8409	13.2017	7.9494	4.8915	5.2522	2
2004	495234	700342	947	13.1128	13.4593	6.8533	6.2595	6.6060	3
2005	621301	774046	883	13.3396	13.5594	6.7833	6.5562	6.7761	4
2006	758237	908855	1091	13.5388	13.7199	6.9948	6.5439	6.7251	5
2007	1175804	1467997	1362	13.9775	14.1994	7.2167	6.7608	6.9827	6
2008	1776666	2386376	1643	14.3902	14.6853	7.4043	6.9860	7.2810	7
2009	2089117	2179695	1626	14.5523	14.5947	7.3939	7.1584	7.2008	8
2010	2331273	1944167	1576	14.6619	14.4803	7.3626	7.2993	7.1177	9
2011	4743593	2073595	1802	15.3723	14.5448	7.4967	7.8757	7.0481	10
2012	4642052	2165489	1772	15.3507	14.5882	7.4799	7.8708	7.1083	11
2013	3475174	3972005	1751	15.0612	15.1948	7.4679	7.5932	7.7268	12
2014	3463868	4064795	1694	15.0579	15.2179	7.4348	7.6230	7.7830	13
2015	4580156	4972260	1561	15.3372	15.4194	7.3531	7.9842	8.0663	14
2016	5100881	5731056	1491	15.4449	15.5614	7.3072	8.1377	8.2542	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.4

PrJSC "Imperial Tobacco Production Ukraine"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2004	594367	428154	830	13.2953	12.9672	6.7214	6.5738	6.2458	1
2005	696674	443179	632	13.4541	13.0017	6.4489	7.0052	6.5528	2
2006	768990	511788	737	13.5528	13.1457	6.6026	6.9502	6.5431	3
2007	818681	605117	654	13.6154	13.3132	6.4831	7.1323	6.8301	4
2008	985289	910554	830	13.8007	13.7218	6.7214	7.0793	7.0004	5
2009	1273453	1044204	594	14.0572	13.8588	6.3869	7.6704	7.4719	6
2010	1368664	1603051	632	14.1293	14.2874	6.4489	7.6805	7.8385	7
2011	1263960	2361887	604	14.0498	14.6750	6.4036	7.6462	8.2714	8
2012	1149488	2037971	573	13.9548	14.5275	6.3509	7.6039	8.1766	9
2013	1028851	2145584	507	13.8440	14.5789	6.2285	7.6154	8.3504	10
2014	1308195	2442097	491	14.0842	14.7084	6.1964	7.8877	8.5119	11
2015	1896018	3613177	485	14.4553	15.1001	6.1841	8.2711	8.9159	12
2016	2051886	4816838	470	14.5343	15.3876	6.1527	8.3815	9.2349	13

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.5

PJSC "DniproAzot"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	439394	954323	5269	12.9932	13.7688	8.5696	4.4236	5.1992	1
2003	675368	1288290	5617	13.4230	14.0688	8.6336	4.7895	5.4353	2
2004	830683	1449140	5504	13.6300	14.1865	8.6132	5.0168	5.5733	3
2005	955068	1654663	4940	13.7695	14.3191	8.5051	5.2644	5.8140	4
2006	1052674	1707280	4785	13.8668	14.3504	8.4732	5.3936	5.8772	5
2007	1185938	1952442	4440	13.9860	14.4846	8.3984	5.5876	6.0862	6
2008	1618160	2911528	4290	14.2968	14.8842	8.3640	5.9328	6.5201	7
2009	1921388	2312521	4241	14.4686	14.6538	8.3526	6.1160	6.3013	8
2010	1985641	3264897	4269	14.5015	14.9987	8.3591	6.1423	6.6396	9
2011	2668215	3253167	4166	14.7969	14.9951	8.3347	6.4622	6.6604	10
2012	2797740	2540878	4120	14.8443	14.7480	8.3236	6.5207	6.4244	11
2013	2740889	2151392	4079	14.8238	14.5816	8.3136	6.5102	6.2680	12
2014	3529838	4350849	4035	15.0768	15.2859	8.3028	6.7740	6.9831	13
2015	5616857	3028116	4013	15.5413	14.9235	8.2973	7.2440	6.6262	14
2016	5245343	3765020	4018	15.4729	15.1413	8.2985	7.1743	6.8427	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.6

PJSC "Kyivmedpreparat"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	144125	131212	1161	11.8784	11.7846	7.0570	4.8214	4.7275	1
2003	143202	189105	1118	11.8720	12.1501	7.0193	4.8527	5.1308	2
2004	200502	229393	1122	12.2086	12.3432	7.0229	5.1857	5.3203	3
2005	239709	278492	1139	12.3872	12.5371	7.0379	5.3493	5.4992	4
2006	192553	326195	1018	12.1681	12.6953	6.9256	5.2425	5.7697	5
2007	233287	406548	898	12.3600	12.9155	6.8002	5.5599	6.1153	6
2008	290477	859248	806	12.5793	13.6638	6.6921	5.8872	6.9717	7
2009	429646	963213	782	12.9707	13.7780	6.6619	6.3089	7.1162	8
2010	541161	1091761	830	13.2015	13.9033	6.7214	6.4800	7.1819	9
2011	550533	1266420	869	13.2186	14.0517	6.7673	6.4513	7.2844	10
2012	685992	1267015	1028	13.4386	14.0522	6.9354	6.5033	7.1168	11
2013	692057	1264927	1033	13.4474	14.0505	6.9402	6.5072	7.1103	12
2014	989951	1377430	1110	13.8054	14.1357	7.0121	6.7933	7.1236	13
2015	1407546	1437076	1199	14.1574	14.1781	7.0892	7.0681	7.0889	14
2016	1602316	1331287	1138	14.2870	14.1017	7.0370	7.2499	7.0646	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.7

PJSC "Southern mining and processing plant"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	144125	131212	1161	11.8784	11.7846	7.0570	4.8214	4.7275	1
2003	143202	189105	1118	11.8720	12.1501	7.0193	4.8527	5.1308	2
2004	200502	229393	1122	12.2086	12.3432	7.0229	5.1857	5.3203	3
2005	239709	278492	1139	12.3872	12.5371	7.0379	5.3493	5.4992	4
2006	192553	326195	1018	12.1681	12.6953	6.9256	5.2425	5.7697	5
2007	233287	406548	898	12.3600	12.9155	6.8002	5.5599	6.1153	6
2008	290477	859248	806	12.5793	13.6638	6.6921	5.8872	6.9717	7
2009	429646	963213	782	12.9707	13.7780	6.6619	6.3089	7.1162	8
2010	541161	1091761	830	13.2015	13.9033	6.7214	6.4800	7.1819	9
2011	550533	1266420	869	13.2186	14.0517	6.7673	6.4513	7.2844	10
2012	685992	1267015	1028	13.4386	14.0522	6.9354	6.5033	7.1168	11
2013	692057	1264927	1033	13.4474	14.0505	6.9402	6.5072	7.1103	12
2014	989951	1377430	1110	13.8054	14.1357	7.0121	6.7933	7.1236	13
2015	1407546	1437076	1199	14.1574	14.1781	7.0892	7.0681	7.0889	14
2016	1602316	1331287	1138	14.2870	14.1017	7.0370	7.2499	7.0646	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.8

PJSC "Motor Sich"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	995330	1695839	23042	13.8108	14.3437	10.0451	3.7658	4.2986	1
2003	1155390	1847586	25736	13.9599	14.4294	10.1556	3.8043	4.2737	2
2004	1083119	1924163	25941	13.8954	14.4700	10.1636	3.7318	4.3064	3
2005	1090406	2057350	24815	13.9021	14.5369	10.1192	3.7829	4.4177	4
2006	1237573	2267439	23028	14.0287	14.6342	10.0445	3.9842	4.5897	5
2007	1749747	2924979	21660	14.3750	14.8888	9.9832	4.3918	4.9056	6
2008	2056424	3537314	21236	14.5365	15.0789	9.9635	4.5730	5.1154	7
2009	3740353	4210663	20832	15.1347	15.2531	9.9442	5.1904	5.3089	8
2010	5001803	6141903	21860	15.4253	15.6306	9.9924	5.4329	5.6382	9
2011	5792524	8182339	25074	15.5721	15.9175	10.1296	5.4425	5.7879	10
2012	7928376	11478776	26832	15.8860	16.2560	10.1974	5.6886	6.0587	11
2013	8583924	13186439	26365	15.9654	16.3947	10.1798	5.7856	6.2149	12
2014	10730122	16579454	27053	16.1886	16.6237	10.2056	5.9830	6.4181	13
2015	13824039	20629148	26040	16.4419	16.8422	10.1674	6.2745	6.6748	14
2016	10546207	25125654	24616	16.1713	17.0394	10.1112	6.0601	6.9282	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table A.9

PJSC "DTEK Dniproenergo"

Years	Q, thousand UAH	K, thousand UAH	L, persons	ln Q	ln C	ln L	ln Q – ln L	ln C – ln L	t
2002	1814820	2785790	10071	14.4115	14.8400	9.2174	5.1941	5.6226	1
2003	1787360	2884150	9934	14.3963	14.8747	9.2037	5.1925	5.6710	2
2004	1732666	2735135	10207	14.3652	14.8217	9.2308	5.1343	5.5909	3
2005	2081363	2773060	9788	14.5485	14.8355	9.1889	5.3596	5.6465	4
2006	2783744	2188302	9825	14.8393	14.5986	9.1927	5.6466	5.4060	5
2007	3824318	2473517	9880	15.1569	14.7212	9.1983	5.9586	5.5229	6
2008	4676320	3406083	9950	15.3580	15.0411	9.2053	6.1527	5.8357	7
2009	4210710	3365592	10034	15.2531	15.0291	9.2137	6.0394	5.8154	8
2010	6227870	4170768	8671	15.6445	15.2436	9.0677	6.5768	6.1759	9
2011	8622309	6207540	8077	15.9699	15.6413	8.9968	6.9731	6.6445	10
2012	9231247	7790456	7090	16.0381	15.8684	8.8664	7.1717	7.0020	11
2013	9766066	9127078	6598	16.0944	16.0268	8.7945	7.2999	7.2322	12
2014	9764306	12042559	4438	16.0942	16.3040	8.3980	7.6963	7.9060	13
2015	7297957	14568876	4119	15.8031	16.4944	8.3234	7.4797	8.1710	14
2016	14137011	19856839	3815	16.4643	16.8041	8.2467	8.2176	8.5574	15

Source: Calculation based on data from annual financial statements available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Appendix B

Results of Tinbergen-Solow production function simulation

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,996027413**							
R-squared	**0,992070607**							
Normalized R-squared	0,990484728							
Standard Error	0,097317666							
Observations	13							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	11,8491176	5,924558799	**625,565291**	3,13473E-11	**35,37132429**		
Balance	10	0,094707281	0,009470728					
Total	12	11,94382488						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	2,627392235	0,549359628	4,782645282	0,000742767	1,403342703	3,851441766	1,403342703	3,851441766
α	**0,190012961**	0,133075319	1,427860267	0,183808092	-0,106497328	0,486523249	-0,106497328	0,486523249
γ	**0,215321775**	0,028675001	7,509041612	2,0415E-05	0,151429891	0,279213658	0,151429891	0,279213658
A	**13,8376375**							
β	**0,809987039**							

Fig. B.1. **PrJSC "DTEK Pavlogradugol"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	0,979826703							
R-squared	0,960060367							
Normalized R-squared	0,953403762							
Standard Error	0,275609084							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	21,9110291	10,95551455	**144,226719**	4,05905E-09	**16,98391704**		
Balance	12	0,911524408	0,075960367					
Total	14	22,82255351						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	0,48825459	0,412385929	1,183974902	0,259345593	-0,410257163	1,386766343	-0,410257163	1,386766343
α	**0,94817518**	0,056161615	16,88297577	9,98187E-10	0,825809534	1,070540827	0,825809534	1,070540827
γ	**-0,07384304**	0,016670094	-4,429671503	0,000821561	-0,110164054	-0,037522025	-0,110164054	-0,037522025
A	**1,629469644**							
β	**0,05182482**							

Fig. B.2. **PJSC "Myronivsky Hliboproduct"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,955795207**							
R-squared	**0,913544477**							
Normalized R-squared	0,899135223							
Standard Error	0,322789192							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	13,21162291	6,605811456	**63,3998462**	4,17596E-07	**11,26053695**		
Balance	12	1,250314349	0,104192862					
Total	14	14,46193726						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	2,192683113	1,055735604	2,076924473	0,05994861	-0,107567165	4,492933391	-0,10756717	4,492933391
α	**0,566997181**	0,190764533	2,972235832	0,01165267	0,151356969	0,982637393	0,151356969	0,982637393
γ	**0,102217634**	0,040930999	2,497315918	0,02805319	0,013036649	0,191398619	0,013036649	0,191398619
A	**8,959219493**							
β	**0,433002819**							

Fig. B.3. **PrJSC "Kalsberg Ukraine"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,959198121**							
R-squared	**0,920061035**							
Normalized R-squared	0,904073243							
Standard Error	0,163551825							
Observations	13							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	3,078710909	1,539355454	**57,54772039**	3,26432E-06	**10,72825432**		
Balance	10	0,267491995	0,0267492					
Total	12	3,346202904						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	3,518159298	1,906514734	1,845335489	0,09476682	-0,729820252	7,766138848	-0,729820252	7,766138848
α	**0,518429326**	0,32032661	1,618439774	0,136637845	-0,195302839	1,232161491	-0,195302839	1,232161491
γ	**-0,000573881**	0,080712823	-0,007110154	0,994466811	-0,180413256	0,179265495	-0,180413256	0,179265495
A	**33,7222986**							
β	**0,481570674**							

Fig. B.4. **PrJSC "Imperial Tobacco Production Ukraine"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,992364917**							
R-squared	**0,984788128**							
Normalized R-squared	0,982252816							
Standard Error	0,114139274							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	10,12072457	5,060362286	**388,4287812**	1,23907E-11	**27,87216465**		
Balance	12	0,156333285	0,013027774					
Total	14	10,27705786						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	2,973812167	0,723892642	4,108084537	0,001451231	1,396585592	4,551038742	1,396585592	4,551038742
α	**0,274164737**	0,134874288	2,032742794	0,064814554	-0,019701092	0,568030566	-0,019701092	0,568030566
γ	**0,159821952**	0,016165331	9,886710542	4,04993E-07	0,124600721	0,195043184	0,124600721	0,195043184
A	**19,56636787**							
β	**0,725835263**							

Fig. B.5. **PJSC "DniproAzot"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	0,986866283							
R-squared	0,97390506							
Normalized R-squared	0,969555904							
Standard Error	0,139430785							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	8,706806972	4,353403486	**223,9296356**	3,15746E-10	**21,16268582**		
Balance	12	0,233291327	0,019440944					
Total	14	8,940098299						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	3,672595498	0,444328317	8,265499546	2,68742E-06	2,704487262	4,640703735	2,704487262	4,640703735
α	**0,187960853**	0,087419214	2,15010916	0,052633016	-0,002509252	0,378430958	-0,002509252	0,378430958
γ	**0,1417563**	0,017739014	7,991216569	3,80242E-06	0,103106309	0,18040629	0,103106309	0,18040629
A	**39,35391645**							
β	**0,812039147**							

Fig. B.6. **PJSC "Kyivmedpreparat"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,968060275**							
R-squared	**0,937140697**							
Normalized R-squared	0,926664146							
Standard Error	0,317992584							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	18,0904956	9,045247798	**89,45126501**	6,16904E-08	**13,37544504**		
Balance	12	1,213431398	0,101119283					
Total	14	19,30392699						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	2,420322088	1,500879254	1,612602801	0,132803426	-0,849812886	5,690457062	-0,849812886	5,690457062
α	0,358269462	0,331782979	1,079830748	0,301443256	-0,364623549	1,081162473	-0,364623549	1,081162473
γ	0,154935061	0,093102245	1,664138827	0,121958476	-0,047917305	0,357787427	-0,047917305	0,357787427
A	**11,24948206**							
β	**0,641730538**							

Fig. B.7. **PJSC "Southern mining and processing plant"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,982245121**							
R-squared	**0,964805477**							
Normalized R-squared	0,958939723							
Standard Error	0,193531174							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	12,3210518	6,160525899	**164,481071**	1,90042E-09	**18,13731353**		
Balance	12	0,449451784	0,037454315					
Total	14	12,77050358						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	-0,387793143	1,531092376	-0,253278737	0,804339893	-3,723756856	2,94817057	-3,723756856	2,94817057
α	0,970856831	0,406251736	2,38979122	0,034148263	0,085710337	1,856003325	0,085710337	1,856003325
γ	0,009417199	0,083873213	0,112278982	0,912458539	-0,173326834	0,192161232	-0,173326834	0,192161232
A	**0,678552692**							
β	**0,029143169**							

Fig. B.8. **PJSC "Motor Sich"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

CONCLUSION OUTCOME								
Regression statistics								
Multiple R	**0,986982412**							
R-squared	**0,974134282**							
Normalized R-squared	0,969823329							
Standard Error	0,176571876							
Observations	15							
Dispersion analysis								
	df	*SS*	*MS*	***F***	*Significance of F*	***t***		
Regression	2	14,09024699	7,045123493	**225,9672735**	2,99466E-10	**21,25875225**		
Balance	12	0,374131531	0,031177628					
Total	14	14,46437852						
	Coefficients	*Standard Error*	*t-statistics*	*P-Value*	*Lower 95%*	*Upper 95%*	*Lower 95.0%*	*Upper 95%*
lnA	3,53553257	0,512027699	6,904963494	1,6395E-05	2,41992005	4,65114509	2,41992005	4,65114509
α	0,230174034	0,106666509	2,157884764	0,051907125	-0,002232324	0,462580392	-0,002232324	0,462580392
γ	0,17315988	0,025463783	6,800241775	1,90226E-05	0,117679063	0,228640697	0,117679063	0,228640697
A	**34,31328408**							
β	**0,769825966**							

Fig. B.9. **PJSC "DTEK Dniproenergo"**

Source: Calculated on the basis of annual financial reports in the MS Excel environment.

Appendix C

The meaning of such indices as Ratio of Intangible Assets to Total Assets, Fixed Asset Renewal & Wear and Tear of Fixed Assets Coefficient

Table C.1

PrJSC "DTEK Pavlogradugol"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2004	0.291	0.037	0.343
2005	0.283	0.093	0.349
2006	0.313	0.086	0.444
2007	0.270	0.158	0.453
2008	0.323	0.159	0.447
2009	0.450	0.615	0.388
2010	0.328	0.118	0.451
2011	0.335	0.489	0.076
2012	0.427	0.189	0.211
2013	0.418	0.161	0.310
2014	0.270	-0.054	0.069
2015	0.188	0.546	0.085
2016	0.222	0.169	0.204
On the average	**0.317**	**0.213**	**0.295**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.2

PJSC "Myronivsky Hliboproduct"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.005	4.021	0.025
2003	0.036	1.337	0.058
2004	0.026	0.615	0.081
2005	0.032	1.068	0.094
2006	0.369	1.305	0.148
2007	0.346	0.548	0.160
2008	0.242	0.175	0.212
2009	0.223	0.125	0.235
2010	1.737	0.561	0.250
2011	1.714	0.177	0.280
2012	1.422	0.325	0.268
2013	2.164	0.336	0.271
2014	1.289	0.418	0.041
2015	2.464	0.265	0.305
2016	0.111	1.358	0.206
On the average	**0.812**	**0.842**	**0.176**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.3

PrJSC "Kalsberg Ukraine"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.682	0.129	0.353
2003	0.508	0.133	0.377
2004	0.907	1.259	0.229
2005	1.122	0.117	0.286
2006	1.245	0.117	0.334
2007	0.928	0.595	0.264
2008	0.745	0.500	0.245
2009	1.044	0.085	0.245
2010	1.742	0.292	0.305
2011	1.813	0.126	0.388
2012	2.173	0.101	0.429
2013	1.542	0.043	0.476
2014	1.834	0.045	0.522
2015	1.733	0.034	0.576
2016	1.722	0.021	0.615
On the average	**1.316**	**0.240**	**0.376**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.4

PrJSC "Imperial Tobacco Production Ukraine"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2004	0.181	0.074	0.362
2005	0.219	0.162	0.404
2006	0.159	0.088	0.445
2007	0.137	0.347	0.379
2008	0.098	0.214	0.361
2009	0.057	0.152	0.382
2010	0.039	0.157	0.429
2011	0.028	0.018	0.379
2012	0.067	0.077	0.388
2013	0.321	0.111	0.404
2014	0.288	0.010	0.456
2015	1.060	0.245	0.419
2016	0.795	0.200	0.400
On the average	**0.265**	**0.143**	**0.401**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.5

PJSC "DniproAzot"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.683	0.017	0.545
2003	0.511	0.010	0.554
2004	0.392	0.003	0.566
2005	0.347	0.012	0.576
2006	0.320	-0.009	0.588
2007	0.275	0.060	0.572
2008	0.168	0.032	0.572
2009	0.202	0.025	0.584
2010	0.123	0.026	0.672
2011	0.092	0.027	0.759
2012	0.091	0.029	0.764
2013	0.105	0.018	0.763
2014	0.059	0.054	0.743
2015	0.086	0.031	0.742
2016	0.068	0.015	0.758
On the average	**0.235**	**0.023**	**0.651**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.6

PJSC "Kyivmedpreparat"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.457	0.420	0.322
2003	0.403	0.251	0.320
2004	0.184	0.149	0.337
2005	0.395	0.192	0.354
2006	0.697	0.180	0.375
2007	1.013	0.116	0.408
2008	0.471	0.066	0.453
2009	0.426	0.134	0.466
2010	0.396	-0.433	0.490
2011	0.358	1.090	0.521
2012	0.054	0.046	0.547
2013	0.431	0.116	0.537
2014	0.498	0.109	0.529
2015	0.991	0.077	0.526
2016	1.289	0.105	0.541
On the average	**0.537**	**0.174**	**0.448**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.7

PJSC "Southern mining and processing plant"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0	0.001	0.462
2003	0.058	0.047	0.483
2004	0.063	-0.020	0.504
2005	0.069	0.059	0.525
2006	0.040	0.052	0.542
2007	0.035	0.017	0.578
2008	0.018	0.074	0.562
2009	0.029	0.036	0.580
2010	0.022	1.365	0.173
2011	0.006	0.071	0.300
2012	0.005	0.080	0.389
2013	0.009	0.173	0.449
2014	0.009	-0.287	0.105
2015	0.070	0.153	0.184
2016	0.421	0.148	0.283
On the average	**0.057**	**0.131**	**0.408**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.8

PJSC "Motor Sich"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.590	0.073	0.550
2003	0.638	0.096	0.555
2004	0.655	0.083	0.562
2005	0.827	-0.523	0.562
2006	0.609	0.020	0.576
2007	0.482	1.592	0.569
2008	0.408	0.074	0.568
2009	0.362	0.082	0.565
2010	0.273	0.192	0.526
2011	0.342	0.312	0.451
2012	0.007	0.201	0.237
2013	0.006	0.173	0.272
2014	0.015	0.201	0.271
2015	0.013	0.163	0.340
2016	0.030	0.187	0.375
On the average	**0.350**	**0.195**	**0.465**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Table C.9

PJSC "DTEK Dniproenergo"

Years	Ratio of Intangible Assets to Total Assets (*RIA*), %	Fixed Asset Renewal (*FAR*)	Wear and Tear of Fixed Assets Coefficient (*WTC*)
2002	0.096	0.007	0.777
2003	0.115	0.025	0.780
2004	0.122	0.005	0.793
2005	0.164	0.010	0.807
2006	0.214	0.030	0.806
2007	0.274	0.021	0.810
2008	0.252	0.059	0.786
2009	0.396	0.012	0.797
2010	0.328	0.018	0.804
2011	0.229	0.015	0.819
2012	0.306	0.202	0.103
2013	0.325	0.202	0.232
2014	0.270	-0.026	0.036
2015	0.271	0.996	0.066
2016	0.330	0.007	0.187
On the average	**0.246**	**0.105**	**0.574**

Source: Calculated according to annual financial reports of enterprises available at the Official website of Stock market infrastructure development agency of Ukraine (SMIDA).

Agenda Publishing House

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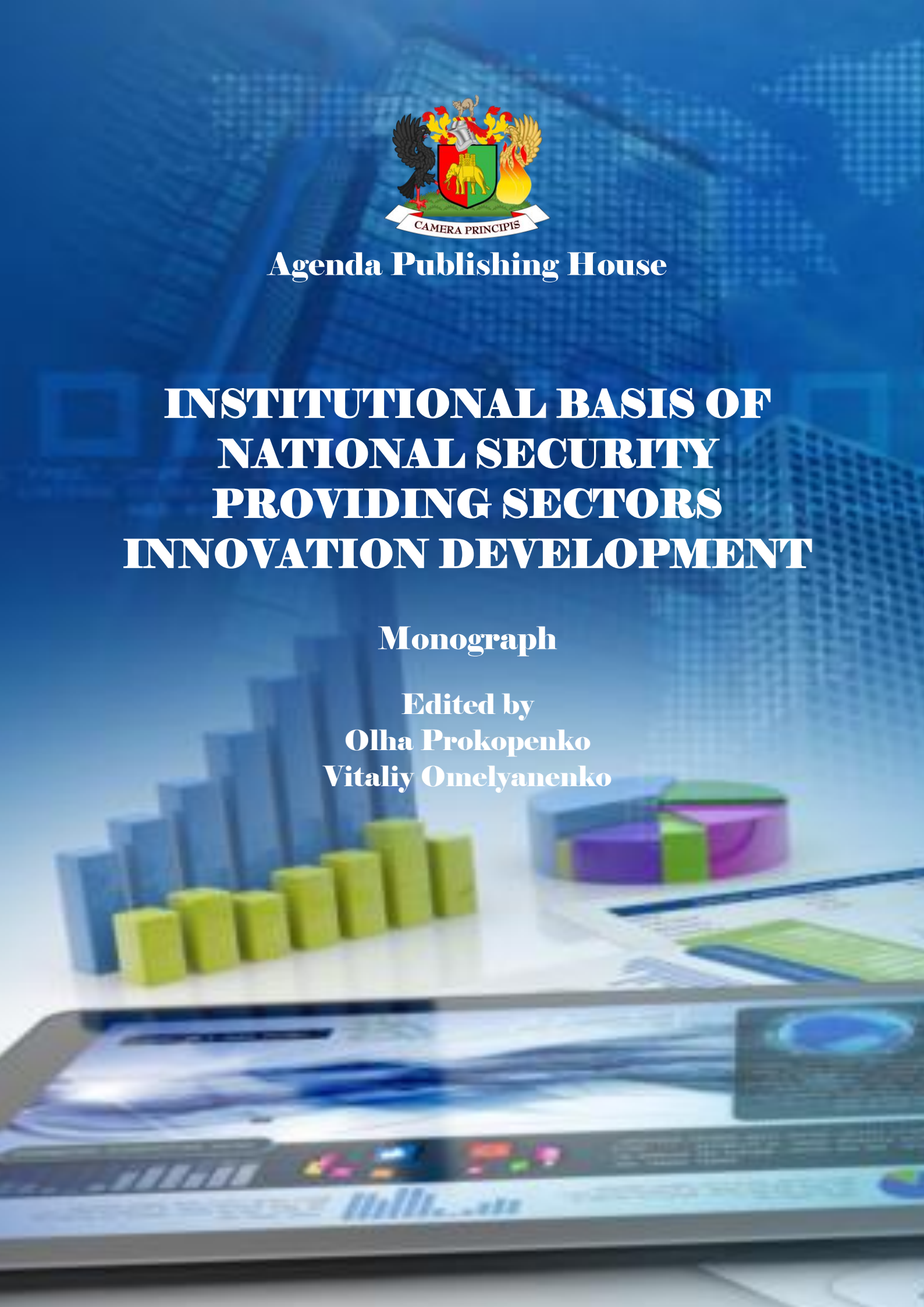

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Agenda Publishing House
United Kingdom
2018

UDK 005.342:351.863
I 68

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I 68 **Institutional Basis of National Security Providing Sectors Innovation Development**: monograph / edited by Dr. of Economics, Prof. O. Prokopenko, PhD in Economics V. Omelyanenko. – Agenda Publishing House, Coventry, United Kingdom, 2018. – 263 p.

ISBN 978-0-9955865-7-1

Monograph is devoted to the research of theoretical and practical aspects of institutional basis of national security providing sectors innovation development. Different institutional methodic approaches and economic mechanisms to provide innovation security at the regional, national and international levels are considered. Scientifically grounded recommendations to achieve economic, financial, social and ecological aims of the national security through the institutional mechanisms are given.

Keywords: institutions, national security, innovation activities, innovation security, international economic relations, innovation policy, technology transfer, investment, policy, management, economic mechanisms.

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INTRODUCTION

Monograph is devoted to the research of theoretical and practical aspects of the innovation security. Different innovation methodic approaches and economic mechanisms to provide innovation security at the regional, national and international levels are considered. Scientifically grounded recommendations to achieve economic, financial, social and ecological aims of the national security through the strengthening of innovation system are given.

The first part «**Institutional basis of technological & innovation systems security**» consider the main aspects of system security providing institutional concept within the technological & innovation systems research methodology development through the institutional innovations. The author consider how the new evolutionary institutional theory of economic systems in the context of the space-time approach can help in organizing strategic management of development path of innovation system, increasing system security and effectiveness of its activities through the balance of system structure.

The second part «**Philosophical analysis of modern status of informational society in the conditions of necessity of innovation networks designing**» deals with the problems, contradictions and prospects of information society, philosophical analysis of information-network paradigm (context of convergence of modern high technologies) and institutional basis of innovation development within the information society transformation.

The third part «**Organizational and legal framework of formation of the institutional preconditions for the investment processes development as a factor of ensuring economic security**» is aimed at establishing the theoretical framework of developing a methodological basis for investment processes management based on the study of relevant foreign experience as well as on analyzing the current organizational and legal principles of the government investment policy. Author presents suggestions on the improvement of the institutional and legal field of investment activity in the context of economic security.

The fourth part «**Integrated assessment of technological development of industrial production in Ukraine**» deals with the development of the effective means to strengthen the national security of the state, it is necessary to study the dynamics of the industrial production technological development.

In the fifth part «**Crowdfunding as a financial institution of innovation**

projects implementation» crowdfunding is considered as a mechanism for financing small and medium-sized businesses and contribute to the transition to an innovation type of economic development.

The aim of sixths part «**Institutional strategy of integrating into the global value chains (space industry case)**» is to analyse the features of integration of countries, different public and private actors involved in space industry development and in global value chains and national industry technology package optimization based on the analysis of global value chains to ensure national technological independence.

In the seventh part «**Mechanisms of the improvement of the management of the innovation development in the field of tourism**» the formation of the innovation tourism clusters is considered as a competitive advantage of the regional structure and the tourism development and the mechanisms of the improvement of the regional structure of tourism industry, development of the infrastructure, the image brands and the routes for the direction of the tourism activities were proposed.

The eighth part «**General theoretical bases of tax transaction costs planning**» deals with the analysis of concept, essence and content of transaction costs of industrial enterprises, considering category «taxes» as a kind of transaction costs of industrial enterprises and development of fundamental principles of tax planning at enterprises.

The ninth part «**Institutional bases of conflicts management in state administration field**» is aimed at analysis of scientific views on the problem of conflicts in the field of state administration, conflicts characteristics in the field of state administration, ways of conflicts regulation and management in the field of state administration and recommendations on conflicts levelling development.

The authors of this monograph are scholars and practitioners from different countries, including **Italy**, **Poland** and **Ukraine**:

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The publication was publicly funded by Ministry of Education and Science of Ukraine for developing of research project № 0117U003855 «**Institutional and technological design of innovation networks for Ukraine national security systemic providing**» and contains the results of studies conducted by President's of Ukraine grant for competitive project № 0118U005233 «**Formation mechanisms of strategic management in national security of Ukraine area based on innovation system systemic stability**» of the State Fund for Fundamental Research.

Scientific edition

Institutional Basis of National Security Providing Sectors Innovation Development

Monograph

Edited by:
Olha Prokopenko
Vitaliy Omelyanenko

ISBN 978-0-9955865-7-1

Paper format A4. Conv. pr. sheets. 15,11. Conv. ed. sheets. 18,01 Edition 100 ex.
Accepted for publication on November 30, 2018

Published by:
Agenda Publishing House,
Coventry, United Kingdom