The system of Simultaneous Equations in Regional Economic Potential Assessment within Smart Specialisation Framework

Alla Ivashchenko[1], Yevheniia Polishchuk[2], Nataliia Datsenko[3]

[1]Kyiv National Economic University named after Vadim Hetman, Corporate finance and controlling department, Kyiv, Ukraine
[2]Kyiv National Economic University named after Vadim Hetman, Corporate finance and controlling department, Kyiv, Ukraine
[3]Kyiv National Economic University named after Vadim Hetman, Economic and Mathematical Modeling Department
[1]alla.ivashchenko@kneu.edu.ua, [2]yivga_83@ukr.net,
[3]*d_tashakneu@ukr.net*

Abstract. In the article the authors developed the model of economic potential assessment based on systems of simultaneous equations and its step-by-step algorithm of realization for Smart specialisation framework. This mathematical apparatus allows to identify the links between the key (basic) factors that are the formative (determining) complex economic objects, which is the economic potential of the region. The use of systems of simultaneous equations is relevant for different areas of study: forecast, management or scenario calculations, which could be widely used in Smart specialisation processes.
The research results will be useful for key stakeholders of Smart specialisation project (regional authorities, business, academic sector and NGOs) in order to choose the priorities of regional innovation policy during Entrepreneurial discovery process. The research is done within the project "The SMEs' development models in the context of regional Smart Specialisation".

Keywords: Economic Potential, Smart Specialisation, Assessment Methodology, Systems of Simultaneous Equations, Stakeholders.

1 Introduction

Ongoing process of regional policy reformation in Ukraine in context of Smart Specialisation (here and after SS) presupposes the detailed exploration of possible approaches of its implementation, in which the assessment of economic potential plays the key role. The priority directions are selected on the basis of evaluation of regional economic potential aimed at their further development and support. So, specification of relevant methods which could be suitable for conducting such assessment in the conditions of high level of shadow economy and lack of transparency and reliability data is very important within SS framework.

Therefore, the aim of this paper is to assess the effects of endogenous variables and exogenous variables on economic potential of the region during SS priorities identification. The methodology can be used by regional authorities, business, academic sector and NGOs. Understanding the link between economic potential assessment and SS strategy will help potential stakeholders and policymakers to perform quantitative methods (the first stage of SS strategy) and Entrepreneurial Discovery Process (the second stage), based on qualitative methods.

2 Literature Review

Different approaches exist in the literature regarding to the economic potential in general. Some studies relate to economic potential with economic growth (Breuer, Guajardo and Kinda, [1], Fukase, Martin, 2016 [2]), others evaluate the socio-economic potential of rural areas, taking into account resources available to these areas (Sompolska-Rzechula, Olenczuk-Paszel and SpiewakSzyjka, 2019 [3]) and other industries (Hoogwijk, de Vries, Turkenburg, 2004 [4]).

Others hold the opinion that the higher economic potential is found in a country the most involved in global value chains it is (Cieslik, Bieganska, Sroda-Murawska, 2019 [5]). Slusarciuc proved the hypothesis about direct proportion relationship between the value of creditworthiness and the size of the municipality (2015 [6]). Economic potential is considered at the global level in the context of marginal costs of non-renewable resources and the price of energy commodities impact (Mercure, Salas, 2013 [7]). It was revealed positive correlation between regional economic development indicators and the education system on the example of Silesian region (Wisniewska-Salek, 2017 [8]).

Some claim that traditional imagination of economic potential is insufficient and there is a need to review the existing approaches in order to design new methodology of the regional evaluation system (Le Cacheux [9]). Other scholars try to apply the economic potential definition with investment project appraisal (Tepliuk [10]).

The methodology of regional economic innovation potential is proposed by the scholars from Joint research Center (JRC) with further application to Smart specialization process. The last provides by the economic and innovation potential calculation. The industries which has 3-5% percent growth per year is taken into account and regarded as those which probably will be identified as priority [11]. The big data massive is analyzed. However, it does not take into considering the factors which can increase or decrease the economic potential of the region.

3 Research Methodology and Data

The construction of econometric, isolated regressions is not sufficient to describe complex systems (e. g. economic potential) and the mechanism of its operation. One factor cannot change without changing the other. In addition, econometric regression makes it difficult to detect spatial effects and spatial relationships between components in the system. Therefore, structural (simultaneous) equation systems that provide unbiased,

efficient, and consistent estimates of mathematical model parameters play an important role in describing the structure of relationships between economic performance indicators.

The study was based on the data of the State Statistics Service of Ukraine. The set of the data includes such indicators as Index of physical volume of GRP; Financial results before taxation by regions; Volume of sales of products (goods, services) of enterprises by region; Level of profitability; Number of employed population (thousand persons); Capital investments by type of activity; Consumer price indices by region (in the previous year, percent); Financial results before tax by region. The given data is divided into two groups namely exogenous and endogenous variables, the level of dependence between each of them in every particular case.

4 Theoretical Grounds to the Assessment of Regional Economic Potential

As we explored previously [12], the basis of SS concept is referred to the idea of economic specialisation and the ability of a country/region to build a competitive advantage on unique, locally based expertise that can be applied in a new and innovative manner. Regional policy in the context of SS enables more productive use of existing resources in the region.

The development of the regional economic potential is impossible without deep understanding of its structure and characteristics of its elements, aimed at their further assessment, it is reasonable to conduct a more detailed study of the economic potential structure on the regional level (fig. 1).

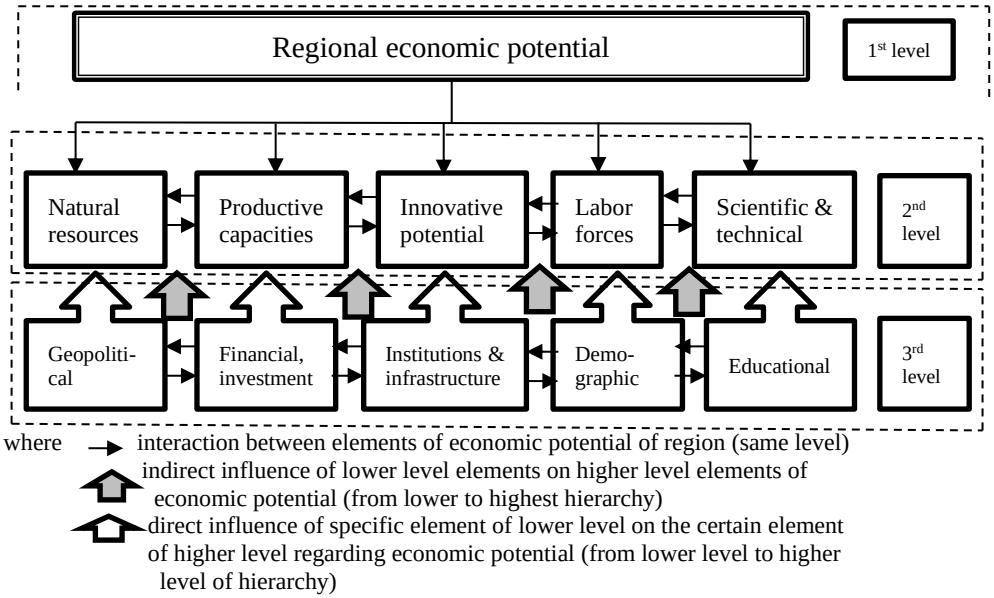

Fig. 1. Organizational mechanism of economic potential elements regarding identification of approach to its assessment

The structure of the regional economic potential has a hierarchical form, which is due to the subordinate dependence of some types of economic potential to others, which, in turn, form the economic potential of the second level and the economic potential of the third level of regional development (see fig. 1).

Understanding the principles of forming the structure of the economic potential of the region, it is possible not only to plan the economic development on regional level, based on selected priorities within Smart Specialisation framework, but also the whole state, strengthening its position in the world market and geopolitical arena.

But Ukrainian economy is characterized by high level of shadow economy, lack of transparent and reliable data, information asymmetry, insufficient financial support, etc. So, our approach for assessment of regional economic potential presupposes usage of such indicators as production and resource potential (the Index of physical volume of GRP) as well as financial one (Financial results before tax), because they are relevant considering barriers and obstacles for implementation EU principle of Regional policy in Ukraine, which were mentioned above.

5 Modelling of Regional Economic Potential

We suppose the hypothesis that economic potential, as a complex economic system, in the context of regions, consists of two important components: production-resource and financial. In our opinion, characteristic indicators by regions, in particular, for the production and resource potential is the Index of physical volume of GRP, and for financial potential- Financial results before tax (here and after EBT).

An important question is the problem of describing the structure of interaction between variables of this system, which is solved by the so-called structural equation systems. We construct an econometric model that contains the regression equations of GRP and EBT by Region, using data of regional development in Ukraine (2016-2017).

Identify variable models:

- endogenous variables: Y1- Index of physical volume of GRP (growth rate, %); Y2- Financial results before taxation by regions (UAH billion);

- exogenous variables: X1-Volume of sales of products of enterprises by region (UAH billion); X2-Level of profitability (%); X3-Number of employed population (thousand persons); X4-Capital investments by type of activity (billion UAH); X5-Consumer price indices by region (growth rate, %); X6 – EBT (UAH billion).

The use of two-step least squares method (here and later LSM) will be effective only if the coefficient of determination of the summary equations obtained in the first step is sufficiently significant ($R^2 \geq 0{,}7$).

Let's estimate the parameters of the econometric model in structural form, taking instead of the actual values of GRP index (Y1) and the EBT (Y2), their calculated values of Y1* and Y2* from table 1. We obtain an econometric model of the components of economic potential in structural form:

$$\begin{cases} Y1 = 122{,}686 + 0{,}194Y_2 - 0{,}022X1 + 0{,}278X2 - 0{,}399X3; \\ \quad (5{,}08) \quad (1{,}203) \quad (-1{,}76) \quad (1{,}502) \quad (-1{,}102) \\ Y2 = -169{,}20 + 0{,}864Y_1 + 0{,}068X4 + 1{,}420X5 + 0{,}756X6. \\ \quad (5{,}08) \quad (1{,}203) \quad (-1{,}76) \quad (1{,}502) \quad (-1{,}102) \end{cases} \quad (1)$$

The coefficients of determination and Fisher's criteria (R^2 = 0.702 F = 7.54 and R^2 = 0.841, F = 25.138) indicate that the constructed equations of the econometric model are qualitative and reliable. In equations (1), all estimates are statistically significant, which also confirms the reliability of the model and the possibility of its further use.

We calculate the coefficients of elasticity of the factors (%) that are included in each equation of the model:

for the first equations we have - $E_{Y_1/Y_2} = 0{,}008;\ E_{Y_1/X_1} = 0{,}019;$

$E_{Y_1/X_2} = -0{,}019;\ E_{Y_1/X_3} = -0{,}217;$

for the second equations we have - $E_{Y_2/Y_1} = 2{,}040;\ E_{Y_2/X_4} = 0{,}203;$

$E_{Y_2/X_5} = 3{,}694;\ E_{Y_2/X_6} = 0{,}299$.

The elasticity coefficients of the first equation of model (8) show that with the increase of EBT on average in the regions by 1% will lead to an increase of the GRP Index by 0.008%, with the increase in the volume of sales of products of enterprises by regions by 1 % The GRP index increases by 0.019%. Increasing the profitability and employment rate by 1% may lower the GRP Index by 0.019% and 0.217%, respectively.

When analyzing the relationship based on elasticity coefficients, it should be taken into account that the other exogenous variables that are not related to this coefficient do not change. Overall elasticity shows that if all exogenous variables increase by 1%, then the index of physical volume of GRP will decrease by 0.209%.

The elasticity coefficients of the second equation (1) characterize the following correlation: if the GRP Index grows by 1% and the other factors remain constant, then the financial result before tax will increase by 2.04% on average in the regions; If capital investment by type of activity by region will increase by 1% and other factors will become, then EBT by region will increase by 0.203%. Similarly, if Consumer Price Indices by region increase by 1% and other factors become steady, then Financial results will increase by 3.694%. In addition, the increase in EBT by region (2016) made it possible to increase this indicator in 2017 by 0.3%. The total coefficient of elasticity indicates that with the simultaneous increase of all exogenous variables of the second equation by 1%. EBT on average increases by 4,196%.

In general, the econometric model looks like:

$$Y_1 = f(Y_2, X_1, X_2, X_3, u_1) \quad (2)$$

$$Y_2 = f(Y_1, X_4, X_5, X_6, u_2) \quad (3)$$

It follows that the index of physical volume of GRP in equation (2) is an endogenous (dependent) variable, and in (3) an exogenous (independent) variable. EBT are an endogenous (dependent) variable in (3) equation and simultaneously an exogenous (independent) variable in (2). Such interdependence of these two economic indicators is real, and the econometric model describes this dependence, without excluding other factors that also affect these indicators. The equations show that there is a relationship between the explanatory variables and the remnants of the model.

Specify the model in structural (linear) form:

$$\begin{cases} Y1 = a_{12}Y2 + b_{10} + b_{11}X1 + b_{12}X2 + b_{13}X3 + u1 \\ Y2 = a_{22}Y2 + b_{20} + b_{24}X4 + b_{25}X5 + b_{26}X6 + u2 \end{cases} \quad (4)$$

This specification of the econometric system of equations (4) is called the structural form of the model. The structural form of the model reveals the impact of changing any exogenous variable (for example, the number of employees or capital investment by activity) on the value of the endogenous variable (in particular, the GRP Index or EBT). In addition, the ordinary LSM is not suitable for finding the parameters of each of these equations, since this form makes them offset when estimating the parameters. Therefore, to determine the coefficients of a structural model, it is necessary to transform it (model) into a summary form.

We identify the model equation in structural form (4) by checking for each equation the following correlation:

$$k_s - 1 \le m - m_s, \quad (4)$$

where k_s – the number of endogenous variables in the equation; m – the total number of exogenous variables in the model; m_s – the number of exogenous variables in the s-th equation.

For the first and second equations we have $2-1 \le 6-3 \Rightarrow 1 \prec 3$.

This form of model is necessary to obtain: predictive values of endogenous variables, calculated values of endogenous variables and unbiased estimates of the parameters of the structural form of the system of equations. In the summary form, the econometric model (5) will look like:

$$\begin{cases} Y1 = r_{10} + r_{11}X1 + r_{12}X2 + r_{13}X3 + r_{14}X4 + r_{15}X5 + r_{16}X6 + \varepsilon 1 \\ Y2 = r_{20} + r_{21}X1 + r_{22}X2 + r_{23}X3 + r_{24}X4 + r_{25}X5 + r_{26}X6 + \varepsilon 2 \end{cases} \quad (5)$$

To obtain qualitative estimates of the simultaneous equations system parameters it is necessary to choose correctly the method of estimation. The choice of method is determined by system conditions, constraints, and the aggregation of certain criteria.

The parameter estimates for the assumed summary form (6) were obtained using the LSM method for each regression equation separately. We have the following results:

- for equation GRP Physical Volume Index (Y1):

$$Y1 = 2754{,}461 - 0{,}023X1 + 0{,}437X2 - 0{,}312X3 + 0{,}197X4 - 1{,}407X5 - 0{,}045X6 + \varepsilon 1$$
$$(128{,}33) \quad (0{,}012) \quad (0{,}179) \quad (0{,}324) \quad (0{,}127) \quad (1{,}088) \quad (0{,}190) \quad (6)$$
$$R^2 = 0{,}7356 \qquad Froz = 5{,}943$$

- for Equation EBT (Y2)

$$Y1 = 238{,}704 + 0{,}044X1 + 0{,}221X2 + 0{,}904X3 + 0{,}244X4 - 2{,}585X5 + 0{,}780X6 + \varepsilon 2$$
$$(244{,}24) \quad (0{,}022) \quad (0{,},34) \quad (0{,}62) \quad (0{,}24) \quad (2{,}07) \quad (0{,}36) \quad (7)$$
$$R^2 = 0{,}8490 \qquad Froz = 15{,}972$$

The results for $\widehat{Y}_1$ *and* $\widehat{Y}_2$ are presented in the form of table. 2

Table 1. Estimated values of endogenous variables for the consolidated system of equations

Region №	Y1*	Y2*	Region №	Y1*	Y2*
1	104,42	12,51	13	103,69	3,92
2	105,11	-7,41	14	103,57	2,80
3	101,47	37,58	15	102,22	16,77
4	94,36	-12,56	16	99,01	-4,46
5	102,08	4,66	17	103,68	8,17
6	100,39	-2,86	18	105,38	-3,23
7	101,53	19,93	19	98,99	16,71
8	101,03	-2,31	20	102,58	2,26
9	105,25	18,87	21	105,23	3,66
10	100,56	1,95	22	100,28	5,76
11	88,12	-31,63	23	99,79	0,79
12	103,98	9,88	24	103,20	3,24

Source: calculated by the authors

These findings have significant implications for the understanding of how the economic potential is sensitive to the different related factors endogenous and exogenous as well.

6 Results and Conclusions

The approach to assessment of economic potential was based on economic mathematical methods, which allow to reveal the dependence between endogenous variables as resulting indicators and exogenous variables as influential ones.

Multiple regression analysis disclosed the existence of direct and indirect impact of exogenous variables on endogenous variables, in particular:

- direct impact between financial results before taxation and index of physical volume of GRP, volume of sales of products (goods, services) and index of physical volume of GRP, capital investments by type of activity and financial results before taxation, consumer price indices by region and financial results before taxation;
- indirect impact between level of profitability and index of physical volume of GRP, number of employed population and index of physical volume of GRP.

This study establishes a quantitative additional methodological framework for detecting priorities of SS. The present study has several practical applications. Firstly, it points to the use of this methodology by regional authorities in order to assess not only for detecting SS priorities but also for analyzing the development of the region in order to make decision within policy development. Secondly, the business representatives may use it in the decision making process during investment in certain regions. Thirdly, academic sector and NGOs may apply it during forming their strategies identifying key directions of the development.

References

1. Realizing Indonesia's Economic Potential Luis E. Breuer, Jaime Guajardo, and Tidiane Kinda (eds) International Monetary Fund, Washington, DC, 2018 Pp. 310 – 317
2. Emiko Fukase, E., Martin, W. (2016). The Economic Potential of an India-US Free Trade Agreement. Journal of Economic Integration, Vol.31 No.4, December 2016, 774~81 http://dx.doi.org/10.11130/jei.2016.31.4.774
3. Sompolska-Rzechula, A., Olenczuk-Paszel, A., SpiewakSzyjka, M. (2019). Measurement and evaluation of the socio-economic potential of rural areas in Poland. Proceedings of the 2019 International Conference "Economic science for rural development" No 50 Jelgava, LLU ESAF, 9-10 May 2019, pp. 186-193 DOI: 10.22616/ESRD.2019.023
4. Hoogwijk, M; de Vries, B; Turkenburg, W. (2004). Assessment of the global and regional geographical, technical and economic potential of onshore wind energy. Energy economics, Vol 26, Issue 5, pp. 889-919. https://doi.org/10.1016/j.eneco.2004.04.016
5. Cieslik, E. ,Bieganska, J., Sroda-Murawska, S.(2019). Central and Eastern European States from an International Perspective: Economic Potential and Paths of Participation in Global Value Chains. Emerging markets finance and trade, 4, https://doi.org/10.1080/1540496X.2019.1602519
6. Slusarciuc, M. (2015). The economic potential of crossborder areas. Opportunities and threats. Emerging markets queries in finance and business 2014, EMQFB 2014. Procedia Economics and Finance, Vol. 32, pp. 801-808
7. Mercure, JF., Salas, P. (2013). On the global economic potentials and marginal costs of non-renewable resources and the price of energy commodities. ENERGY POLICY, Vol. 63, pp. 469-483
8. Wisniewska-Salek, A. (2017). Education management - the analysis of the economic potential of the silesian region. International Scientific Conference on Knowledge for Market Use - People in Economics - Decisions, Behavior and Normative Models: Olomouc, Czech Republic, Sep 07-08, 2017.pp. 506-515
9. Le Cacheux, J. (2017). Potential growth: Economic policy in the kingdom of the blind. Economy of Region, Issue 4, 2017, Pages 1068-1079
10. Tepliuk M. and others (2019). Policy assessment investment appeal of innovation projects enterprises. International journal of innovative technology and exploring engineering (IJITEE) ISSN: 2278-3075, Volume-9 Issue-2, December 2019 Available at: http://www.ijitee.org/wp-content/uploads/papers/v9i2/B7714129219.pdf., last accessed 2020/02/17.
11. Todeva, E., Rakhmatullin, R. (2016). Global Value Chains Mapping: Methodology and Cases for Policy Makers, JRC Science for Policy Report, European Union, EUR 28085 EN; doi:10.2791/273290
12. Polishchuk Ye., Ivashchenko A., Britchenko Yu., Machashchik P., Shkarlet S. (2019) European Smart Specialisation for Ukrainian Regional Development: Path from Creation to Implementation / Problems and Perspectives in Management. –Volume 17, 2019, Issue№ 2, pp. 376-391. Available at: https://businessperspectives.org/images/pdf/applications/publishing/templates/article/assets/12090/PPM_2019_02_Polishchuk.pdf, last accessed 2020/02/18.