Modeling the Impact of Foreign Investment Flows Taking into Account Time Lags in the Context of their Impact on the Regional Production

Liubov Vodianka, Vira Kozak, Valentyna Skulyak

Abstract: Peculiarities of regional processes of foreign direct investment impact on the gross domestic product of Western Ukraine and Chernivtsi region, taking into account a time lag, are reviewed in this article. Considering the fact that investment processes are enough complicated phenomenon to understand in the course of which different kinds of changes occur, the relevance and importance of establishing a pattern of their behavior is increasing. Economical and mathematical tools, in particular Almon distributed lag models which allow to estimate the discrete lag influence of determinants can be used to achieve this.

In the course of the study, the Almon distributed lag models were constructed separately for the comparison, time lag interval boundaries were set, the main features of the discrete time lag distribution during the lag period were determined, and the economic and mathematical models of the distributed lag for the effects of foreign direct investment on the gross regional product of Chernivtsi region Western Ukraine were built. On the basis of the obtained results, conclusions about economic multiplier processes of the investment were made in the context of individual territories and the main trends of the investment flow return were defined.

Keywords : Modeling the impact of foreign investment flows, time lags, Almon lags, regional production.

I. INTRODUCTION

In the context of current trends of decentralization and focusing on regional development, research of the economic growth of separate territories, taking into account their particularities at the micro and macro levels, is a perspective area of the research. This sphere becomes more relevant with the development of the theory of developmentalism, the theory of innovation and innovative development tends to rethinking in the context of regional development. This topic was researched by foreign economic researchers such as Ronald McQuaid (2015) [2], Philip McCann (2017) [3], Daniel Shefer (2013) [4], Nadir Kinossian (2018) [5] and others. Scientific works and publications of these researchers were related to the consideration of the regional development in the context of attraction of foreign and private investments, consideration of regional economic policy and investments as one of the factors of its formation and study of regional development in the countries of Southeast Europe.

The study of the impact of foreign investment flows on the regional production, taking into account time lags, using economic and mathematical tools, gives an opportunity to consider this phenomenon more specifically and evaluate the efficiency of usage and the multiplier effect on the regional development of separate territories. It is also important to distinguish the development of individual territories in the context of the development of certain regions of the national economy. Consideration of this issue takes place in the context examining the regions of Western Ukraine in contrast to the development of Chernivtsi region, gives an opportunity of more practical assessment of the importance of this issue in the context of modern economic realities.

II. PURPOSE OF THE STUDY

To study and analyze the impact of foreign investment on regional economic growth in the context of the separate territory and the comparison with the development of the whole economic region using economic and mathematical tools, in particular Almon distributed lag models [1]. To perform the analysis on the basis of the main correlation and determination coefficients applying correlation and regression analysis, to build a model of the impact of foreign direct investments on the gross regional product, having made appropriate conclusions.

III. ANALYSIS OF THE MAIN STUDIES AND PUBLICATIONS

It is possible to face the investigation of this issue in the writings of both our and foreign economists, as nowadays the theory of innovation and innovative development tends to rethinking in the context of regional development. This topic was researched by foreign economic researchers such as Ronald McQuaid (2015) [2], Philip McCann (2017) [3], Daniel Shefer (2013) [4], Nadir Kinossian (2018) [5] and others. Scientific works and publications of these researchers were related to the consideration of the regional development in the context of attraction of foreign and private investments, consideration of regional economic policy and investments as one of the factors of its formation and study of regional development in the countries of Southeast Europe.
Similar topics were discussed in the works of our researchers, in particular by Liudia Shynkaruk (2017) [6], Valerii Heyets (2016) [7] and Tatiana Artiomova (2017) [8] and other [9]. Their studies were related to structural changes in the economy, regions and the branch structure of economics in the context of the influence of investment flows.

IV. METHODOLOGICAL FOUNDATION

The tools of economic and mathematical analysis, in particular the Almon distributed lag model, should be used for more detailed analysis. The prerequisite for using this model is the very essence of the definition of the investment. Since this economic resource does not immediately have an effect and may have different influence on the economic system, it is therefore appropriate to take into account the time difference between the investment of the resource and its return, or the so-called time lag. To define the time lag that accompanies a particular phenomenon, a mutually correlative function is used in economic and mathematical modeling which enables to determine the time lag occurring in regression. The general formulation of the correlation function is as follows [1]:

\[ r_t = \frac{\sum_{i=1}^{n} y_{t} x_{t} - \sum_{i=1}^{n} y_{t} \sum_{i=1}^{n} x_{t}}{\sqrt{\left( \sum_{i=1}^{n} y_{t}^2 - \left( \sum_{i=1}^{n} y_{t} \right)^2 \right) \left( \sum_{i=1}^{n} x_{t}^2 - \left( \sum_{i=1}^{n} x_{t} \right)^2 \right)}} \]

where \( n \) – the sample volume; \( r_t \) – the specific time lag; \( t \) – the time period of the consideration of the phenomenon; \( y_t \) – the meaning of the dependent variables in the period \( t \); \( x_t \) – the meaning of the determinant variables in the period \( t \); \( r_t \) – coefficient of the mutual correlation of time lag.

The mutual correlation function determines the most significant time lags. If the lag has a direct correlation, it will exist in the interval (0; 1), and the intensity of the connection of the time lag will be determined by the movement to the value 1. If the lag has an inverse correlation, it will be in the interval (-1; 0), and the intensity will be determined by the movement of the coefficient up to -1.

V. RESULTS AND DISCUSSION

The development of territories and regions in the context of attracting foreign direct investments is an important component of their effective functioning in the current economic realities of any economy. This problem is of particular relevance for the regions and territories of Ukraine, which are currently in the process of decentralization and, accordingly, are seeking opportunities for their own autonomous development and economic growth. It should be admitted, that the multiplier effect of investments in different regions and territories is implemented differently. In particular, considering this phenomenon in comparison with separate economic regions, it can be admitted that the return on investment and investment attractiveness in the Chernivtsi region differs from Kiev or Odessa regions. Therefore, the study of the behavior of investment processes in the territories and regions is significant in determining the positive and negative factors for their implementation and in the search of prospects for improving their investment attractiveness.

Taking into account the data provided by the State Statistics Service of Ukraine, the data on the dynamics of foreign direct investments and the gross regional product of Chernivtsi region as well as of the whole region of Western Ukraine, including Transcarpathian, Chernivtsi, Ivano-Frankivsk, Lviv, Ternopil, Volyn and Rivne regions were distinguished and consolidated. Comparison of development and comparison of features of investment processes in the context of the separate territory and region gives a more complete and objective understanding, regarding their economic development and possibilities of optimization of these economic processes in the future. Table-I provides information on the gross regional product of Chernivtsi region and Western Ukraine during 2010-2018.

Table-I Dynamics of the gross regional product and foreign direct investments of Chernivtsi region and Western Ukraine during 2010-2018

<table>
<thead>
<tr>
<th>Year</th>
<th>Gross regional product of Chernivtsi region (million UAH)</th>
<th>Gross regional product of Western Ukraine (million UAH)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2010</td>
<td>9 892</td>
<td>130 329</td>
</tr>
<tr>
<td>2011</td>
<td>11 969</td>
<td>162 111</td>
</tr>
<tr>
<td>2012</td>
<td>13 166</td>
<td>188 575</td>
</tr>
<tr>
<td>2013</td>
<td>13 757</td>
<td>192 393</td>
</tr>
<tr>
<td>2014</td>
<td>15 049</td>
<td>224 330</td>
</tr>
<tr>
<td>2015</td>
<td>18 506</td>
<td>281 598</td>
</tr>
<tr>
<td>2016</td>
<td>21 239</td>
<td>326 160</td>
</tr>
<tr>
<td>2017</td>
<td>28 591</td>
<td>424 443</td>
</tr>
<tr>
<td>2018</td>
<td>29 877</td>
<td>442 238</td>
</tr>
</tbody>
</table>

Source: Research results – the base for calculations are data from UKRSTAT (2019) [10]

Table-I shows a high enough volatility of the dynamics of the gross regional product and the volume of foreign direct investments both in Chernivtsi region and in Western Ukraine during 2010-2018. Such dynamics demonstrate the direct impact of the crisis macroeconomic distortions experienced by the Ukrainian economy during this period, which have directly or indirectly affected both the investment attractiveness and the stability of the economic systems of the regions and their economic entities, as well as the macro and meso levels.

Taking into account the data and logical assumptions, the results of the function of the mutual correlation were calculated for the samples of the data stated above for Chernivtsi region and Western Ukraine for time lag values in the interval \( \tau = \frac{1}{3} \). The results of the analysis are presented in the Table-II.

Table-II Value of the mutual correlation function for samples of Chernivtsi region and Western Ukraine for the time lag interval \( \tau = \frac{1}{3} \)

<table>
<thead>
<tr>
<th>( \tau )</th>
<th>( r_{\tau} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>-0.3077</td>
</tr>
<tr>
<td>1</td>
<td>+0.1653</td>
</tr>
<tr>
<td>2</td>
<td>+0.7348</td>
</tr>
<tr>
<td>3</td>
<td>+0.8673</td>
</tr>
<tr>
<td>4</td>
<td>+0.7588</td>
</tr>
</tbody>
</table>

Source: Research results – the base for calculations are data from UKRSTAT (2019) [10]
As it can be noticed, the highest correlation of the time lag is observed for the value \( \tau = 3 \) for Chernivtsi region, and \( \tau = 4 \) for Western Ukraine. Graphically, the time lag correlation distribution is shown in the Fig. 1.

Analyzing the time lags, it should be admitted that the speed of realization of investments in Chernivtsi region for one year is faster in comparison with the whole Western Ukraine. This phenomenon should be considered on the plane that, comparing the volume of investments in other territories of Western Ukraine, it can be concluded that too little investment flows from abroad are directed to Chernivtsi and its region, and therefore due to the small scale of projects the realization of investments is occurring faster.

By setting the objective time lag value, the regression of the Almon distributed lag can be constructed. This economic and mathematical model is aimed at studying the discrete effect of time lag, and gives the opportunity to evaluate the realization of investments in the course of the process.

The Almon distributed lag model has the general appearance of the \( n \)-th power polynomial. Each value of the estimation of the regression coefficients \( b_j, j = 1, m \), can be represented as a polynomial of the \( j \)-th power [1]:

\[
\begin{align*}
  b_0 &= c_0 \\
  b_1 &= c_0 + c_1 + \cdots + c_j \\
  b_2 &= c_0 + 2c_1 + 4c_2 + \cdots + 2^j c_j \\
  b_j &= c_0 + \tau c_1 + \tau^2 c_2 + \cdots + \tau^j c_j 
\end{align*}
\] (2)

After making a number of transformations, the polynomial components are replaced with new variables \( Z_k \) in the model. The replacement is carried out according to the following algorithm [1]:

\[
Z_0 = x_t + x_{t-1} + x_{t-2} + \cdots + x_{t-\tau} = \sum_{j=0}^{\tau} x_{t-j}
\] (3)

\[
Z_1 = x_{t-1} + 2x_{t-2} + 3x_{t-3} + \cdots + \tau x_{t-\tau} = \sum_{j=0}^{\tau} jx_{t-j}
\]

\[
Z_2 = x_{t-1} + 2^2 x_{t-2} + 3^2 x_{t-3} + \cdots + \tau^2 x_{t-\tau} = \sum_{j=0}^{\tau} j^2 x_{t-j}
\]

Substituting new variables into the overall expression of the model instead of polynomials, the following view of the time lag distribution model can be received:

\[
y_t = a + c_0 Z_0 + c_1 Z_1 + \cdots + c_j Z_j + \varepsilon \] (4)

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  b_j &= c_0 + \tau c_1 + \tau^2 c_2 + \cdots + \tau^j c_j 
\end{align*}
\] (2)

After making a number of transformations, the polynomial components are replaced with new variables \( Z_k \) in the model. The replacement is carried out according to the following algorithm [1]:

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\] (3)

\[
Z_1 = x_{t-1} + 2x_{t-2} + 3x_{t-3} + \cdots + \tau x_{t-\tau} = \sum_{j=0}^{\tau} jx_{t-j}
\]

\[
Z_2 = x_{t-1} + 2^2 x_{t-2} + 3^2 x_{t-3} + \cdots + \tau^2 x_{t-\tau} = \sum_{j=0}^{\tau} j^2 x_{t-j}
\]

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\[
y_t = a + c_0 Z_0 + c_1 Z_1 + \cdots + c_j Z_j + \varepsilon \] (4)

Considering these manipulations in the context of models of the impact of foreign direct investment on the gross regional product of Chernivtsi region and Western Ukraine, it is worth admitting that in the first case the Almon distributed lag model will be expressed by the third order polynomial and in the second case the second order polynomial. The model construction data are shown in the Table-III.

### Table III Calculations of the Almon model for the sample of Chernivtsi region and Western Ukraine

<table>
<thead>
<tr>
<th>Gross regional product of Chernivtsi region</th>
<th>Direct investments</th>
<th>( Z_0 )</th>
<th>( Z_1 )</th>
<th>( Z_2 )</th>
<th>( Z_3 )</th>
<th>Gross regional product of Chernivtsi region</th>
<th>Direct investments</th>
<th>( Z_0 )</th>
<th>( Z_1 )</th>
<th>( Z_2 )</th>
<th>( Z_3 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>992</td>
<td>61.8</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>130 329</td>
<td>2 846.6</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>11969</td>
<td>61.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>162 111</td>
<td>2 661.1</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13166</td>
<td>61.9</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>188 575</td>
<td>2 947.7</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>13757</td>
<td>64.2</td>
<td>249.8</td>
<td>371.1</td>
<td>865.7</td>
<td>2225.7</td>
<td>192 393</td>
<td>3 151.4</td>
<td>8 760.2</td>
<td>8 269.9</td>
<td>13 594.75</td>
<td>-</td>
</tr>
<tr>
<td>15049</td>
<td>80.2</td>
<td>268.2</td>
<td>373.7</td>
<td>868.9</td>
<td>2230.7</td>
<td>224 380</td>
<td>3 413.8</td>
<td>9 512.9</td>
<td>9 050.33</td>
<td>14 045.73</td>
<td>-</td>
</tr>
<tr>
<td>18506</td>
<td>68.6</td>
<td>274.9</td>
<td>394.3</td>
<td>894.1</td>
<td>2265.1</td>
<td>281 598</td>
<td>2 995.8</td>
<td>9 561</td>
<td>9 716.6</td>
<td>16 019.4</td>
<td>-</td>
</tr>
</tbody>
</table>
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| 21239 | 59.1 | 272.1 | 421.6 | 967.2 | 2443.6 | 326 | 160 | 2736.3 | 9 | 145.9 | 9 | 823.4 | 16 | 651 |
| 28591 | 57.1 | 265 | 436.9 | 1055.3 | 2773.3 | 424 | 443 | 248 | 8 | 220.1 | 8 | 727.9 | 14 | 719.5 |
| 29877.6 | 42.6 | 227.4 | 381.1 | 910.9 | 2382.1 | 442 | 239 | 2632.9 | 7 | 857.2 | 7 | 960.6 | 13 | 433.2 |

Source: Research results – the base for calculations are data from UKRSTAT (2019) [10]

Therefore, during the study, the following models of the distributed Almon lag were obtained. The results of constructing the Almon distributed lag model to simulate the impact of foreign direct investments on the gross regional product of Chernivtsi region and Western Ukraine are shown in the Table-IV.

Table-IV The final view of the Almon distributed lag model in the context of the consideration of foreign direct investments for the gross regional product of Chernivtsi region and Western Ukraine

<table>
<thead>
<tr>
<th>Name</th>
<th>The final formation of the Almon distributed lag model for Chernivtsi region</th>
<th>The final formation of the Almon distributed lag model for Western Ukraine</th>
</tr>
</thead>
<tbody>
<tr>
<td>The general view of the Almon distributed lag model</td>
<td>( y_t = -311.837 - 333.253z_t + 128.6277z_t - 1035.7z_t + 241.6126z_t )</td>
<td>( y_t = 1176711.93 - 314.683z_t + 611.531z_t - 238.419z_t )</td>
</tr>
<tr>
<td>The initial view of the Almon distributed lag model</td>
<td>( \beta_1 = -0.1957, \beta_2 = 0.4582, \beta_3 = -0.167 )</td>
<td>( \beta_1 = 1.04355, \beta_2 = -0.19376, \beta_3 = 0.15022 )</td>
</tr>
</tbody>
</table>

Considering the regressions of Chernivtsi region and Western Ukraine, it should be noted that they have many differences. First of all, it is a time lag. The length of the time lag in the first regression is 3 years, and in the second it is -4. Secondly, analyzing the model itself, it should be admitted that in the Chernivtsi region model of the dependence of the gross regional product on foreign direct investments has a negative linear coefficient b. This shows that the state of the regional gross product will be negative before the beginning of investments. Compared to the sample of Western Ukraine, this feature will be negative, since the coefficient b is positive. In addition, it is worth highlighting the return investment features. Both the first and the second regressions will have sinusoidal forms. The highest investment return is observed for the values \( x_{t-1} = 548.05 \) in Chernivtsi region. In addition, they also have a positive investment effect \( x_{t-1} = 138.94 \). As for the values \( x_{t-2}, x_{t-2} \), they have a negative effect on the regression -333,253 and -50,5272.

VI. CONCLUSION

The greatest impact on the final result is the investment of the last period. Considering that both negative and positive phenomena are available, it is worth admitting that the greatest impact is made by investments at the initial moment of the lag. Their effect can be estimated at 180.7% of the final result. As for the Western Ukraine, the investments will also be sinusoidal. The positive investment result is observed only in the second year of the time lag with the value \( x_{t-1} = 1 \) and the impact is estimated at 58,429 units of the gross regional product growth with the investment growth of this period. In other cases, the negative impact is observed. Speaking about such peculiarities, it is important to point out that the return on investment to Ukraine is a rather volatile phenomenon and depends on the regional policy and the development strategy. Consolidating different regions into the region of Western Ukraine, it is worth admitting that even in such a sufficiently isolated area, there is a considerable economic territorial differentiation by the geographical indication. Therefore, there is a need for a more detailed study of the impact of foreign direct investments on the gross regional product performance of individual territories in the context of the time lag of investment processes.

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