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Infrastructural effects of economic growth: systematic and dynamic approach to assessment as exemplified by Krasnodar Territory

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***Abstract* — The article with due account of pertinent domestic and international experience of similar research presents an adaptive simulation model of Krasnodar Territory, which on the probabilistic basis allows for assessing the contribution of infrastructural update in the change of the gross regional product exemplified by additional flow of traffic across the Crimean Bridge. The potential scenarios of impact of freight traffic volume across the Kerch Straight Bridge upon the regional economic growth are considered also from a perspective of alternative macro-scenarios described by investment activity parameters.**

Keywords — infrastructure, large-scale projects, model, investments; transport, economic growth, Crimean Bridge

I. Introduction

The territorial industrial engineering is a result of actualized possibilities provided by transport, as a potential of economic development is limited by possibility frontier of the transport infrastructure. The transport infrastructure involving high capital-output ratio and rigidity forms a long-term basis of the territory [1].

Large-scale transport projects are such change of the transport system which affects fundamentally technical, social and economic indices of the transport system of regions and the state as whole. More times than not, the projects of a like nature modify a level of development of productive power, structure and production volumes, politico-social conditions in the respective regions.

The immediacy of the problem of the assessment of the impact of large-scale transport projects upon development of Russian regions is increasing due to high deterioration of the existing infrastructure as well as the necessity of creation of new infrastructural sites which are able to boost the development of the corresponding regions.

Solution of this scientific problem requires taking into account of different factors and complicated interrelationships within the framework of the regional social and economic system under consideration, using methods of system analysis and tools of economic and mathematical simulation.

The goal of this article is to define a simulation model of assessment of the impact of transport projects on economic growth of Krasnodar Territory exemplified by the Crimean Bridge project. The immediacy of the problem for this region is determined by intrinsic exhaustion of the model of regional development which was formed in 2000-s and based on the inflow of investments, to a great extent attributable to preparation for the Winter Olympic Games 2014. Herewith the return to the old trajectory of dynamics implemented due to advantages of the regional economy is possible subject to implementation of large projects which can make a significant contribution in the added value formed within this territory.

II. Materials and Methods (Model)

As a tool kit for assessment of direct and indirect effects of implementation of transport projects by consulting companies, the methodology of cost-benefit analysis (CBA) and its modification - social cost-benefit analysis (SCBA) [2] is practiced on a wide scale

The main indices which are analyzed in the complex approach to the assessment of infrastructural projects are benefits of consumers of transport services, expenses on project implementation, effect of changes in transport network, added value generated by the project, influence on employment level, changes of productivity of agents of production on environmental quality.

As noted in [3], recent decades are marked by the boom of research aimed at the development of macroeconomic models as an alternative analytical tool which is used along with CBA/SCBA and complements it allowing for revealing cause-and-effect relations between social indicators of transport sphere and economic growth, structural changes in economy.

In foreign investigations are widely used the vector autoregressive models (VAR model) [4] and the vector error correction [2] as the most adequate tools for revealing feedback between stationary variables under study. However, a significant limitation of applicability of these models is the requirement for time series availability for producing reliable results.

The work [5] is dedicated to assessment of impact of development of federal public road network on regional economic development. The result of investigation was a model which confirmed the importance of influence of public road construction and reconstruction on economic development over the medium term:

- increase in traffic capacity promoted the growth of transport accessibility and investment potential of regions;

- increase in commodity turnover and investments expressed in physical terms brings about the growth of gross regional product (GRP);

- growth of regional economy may trigger an increase in traffic congestion and decline in transport accessibility (existence of the growth ceiling).

In the work of Y.A. Shcherbanin [6] it is noted that there are opposite points of view of relationship between growth of transport and economy as a whole. Thus, some researchers presume that development of transport promotes economic growth, while others insist that there is no direct correlation between development of transportation and economic growth.

Based on closely examined approaches and current experience in construction of economic and mathematical models as well as with due account for available statistical data, there was constructed the author's model of evaluation of infrastructural effects of economic growth of Krasnodar Territory in the context of implementation of the Kerch Straight Bridge project. The model is based on application of the system dynamic method in the iThink environment.

As a main final indicator of the social and economic situation in the region resulting from implementation of the simulated impact of transport infrastructure, we use the indicator of gross regional product (GRP).

The simulation model reflects the parameters of capital management policy, indices of agriculture, industry, transport and gross value added, which has been generated in these sectors, turnover of wholesale trade, highway transport freight turnover, highway transport freight turnover directly connected with construction of the Kerch Straight Bridge (scenario variable), carriage of goods by railway transport, carriage of goods by railway transport directly connected with construction of the Kerch Straight Bridge (scenario variable).

The interrelations of this model's parameters are established by econometrics methods. The variables are selected, on the one hand, according to the logic of model construction, on the other hand from available necessary statistical data.

$$\left\{\begin{array}{ll}
VAdd_ind = 4{,}6024 \cdot {Inv_{ij}}^{0{,}79} & (1)\\
VAdd_agr = 49945 \cdot \lg Inv_{ij} - 525452 & (2)\\
Scenario_1_1_Inv = normal(105{,}65; 0{,}48) & (3)\\
Scenario_2_1_Inv = normal(105{,}65; 0{,}48) & (4)\\
Scenario_1_2_Inv = normal(103{,}45; 0{,}25) & (5)\\
Scenario_2_2_Inv = normal(103{,}45; 0{,}25) & (6)\\
\mathrm{Wh}_Trade = 2{,}54 \cdot (VAdd_ind + VAdd_agr) - 13170 & (7)\\
Trans_auto = 1524{,}4 \cdot \mathrm{Wh}_Trade - 13511 & (8)\\
Trans_railv = 8{,}07 \cdot \lg \mathrm{Wh}_Trade - 75{,}38 & (9)\\
VAdd_Trans = e^{-5{,}16} \cdot Trans_railw^{0{,}79} \cdot Trans_auto^{1{,}61} & (10)\\
Scenario_1_1_Trans_railw = normal(0{,}875;\ 0{,}04) & (11)\\
Scenario_1_1_Trans_auto = normal(262{,}65; 20{,}95) & (12)\\
Scenario_2_1_Trans_railw = normal(1{,}125;\ 0{,}08) & (13)\\
Scenario_2_1_Trans_auto = normal(377{,}3;\ 37) & (14)\\
Scenario_1_2_Trans_railw = normal(0{,}875; 0{,}04) & (15)\\
Scenario_1_2_Trans_auto = normal(262{,}65; 20{,}95) & (16)\\
Scenario_2_2_Trans_railw = normal(1{,}125; 0{,}08) & (17)\\
Scenario_2_2_Trans_auto = normal(377{,}3;\ 37) & (18)\\
VAdd_Trans_Total_{ij} = e^{-5{,}16} \cdot {Scenario_ij_Trans_railw_{ij}}^{0{,}79} \cdot {Scenario_ij_Trans_auto_{ij}}^{1{,}61} & (19)\\
\Delta GRP_{ij} = 2{,}0199 \cdot {VAdd_Trans_Total_{ij}}^{1{,}09} & (20)
\end{array}\right.$$

where: *Vadd_ind* – gross value added in industry, million rubles; *Vadd_agr* – gross value added in agriculture, million rubles; Inv_{ij} – index of physical amount of investments in basic stock in scenario *i_j (i,j=1,2)*, %; I_{ij} – investment in basic stock in scenario *i_j (i,j=1,2)*, million rubles; *Wh_trade* – turnover of wholesale trade, million rubles; *Vadd_Trans* - gross value added in transport, million rubles; $Trans\_railw_{ij}$ – goods carried by railway transport in scenario *i_j (i,j=1,2)*, million tons; $Trans\_auto_{ij}$ - highway transport freight turnover, million tons/km in scenario *i_j (i,j=1,2)*; $Vadd\_Trans\_Total_{ij}$ - gross value added in transport due to bridge operation in scenario *i_j (i,j=1,2)*, million rubles; ΔGDP_{ij} – increment of gross regional product due to operation of the bridge in scenario *i_j (i,j=1,2)*, million rubles.

Let's describe the logic of simulation model construction and its structural bonds:

1. An increase in investments in basic stock (*I_{ij} и Inv_{ij} - independent/exogenous variables)* promotes the growth of production in manufacturing sectors – industry and agriculture (endogenous, dependent variables of these branches *"Vadd_ind" and "Vadd_agr"* in equations (1) and (2), correspondingly. As a rule, this effect manifests itself behind time due to existence of a time lag between the time of investment and the start of production growth. However, in the context of equations under consideration, constructed from data over the period 2000-2015, a significant type of dependence was obtained for yearly data without delay. That is, for the period under consideration, the effect of investments, on average, significantly influences economic growth already in the year of implementation. This trend may result from low-added value products of industry and agriculture which require shorter investments. Another factor in a significant part of time series under consideration might be considerable investments in pre-Olympic infrastructure development of the region, construction works underlying the material multiplicative effect. Such estimate may be indirectly confirmed by the structure of investments in basic stock. Particularly, in 2013, the difference between the share of investments in building and structures, and investments in machinery and equipment in Krasnodar Territory was 21.5% (50.2% against 28.7%), while in other federal districts over the

same period in majority of cases the difference was 5% at least.

Reduction of investments coincides with the recession periods and also is a reason of reduction in performance efficiency, as a consequence – lowering of value added for most segments of economic activity. Besides, reduction of investments in development of infrastructure increases the load on transport network followed by increase in transport expenses of production and, all other conditions being equal, lowers production output and employment.

2. Investment index is preset as a scenario variable distributed according to the normal probability law, which parameters are changed depending on a scenario.

3. Wholesale trade turnover (turnover rate: *Wh_trade – dependent variable (7)*) depends on value added in industry and agriculture (independent variables in equation (3), but endogenous within the model: are defined in equations 1 and 2): the higher is a gross value added in industry and agriculture, the higher is a wholesale trade turnover. That is, a direct dependence is assumed: a higher is a level of output – a higher is a wholesale trade turnover.

4. Increase in rate of trade turnover *(*variable *Wh_trade –* independent in equations 8 and 9, but endogenous within the model: dependent for equations 7) directly influences carriage of goods by overland transport (from available statistical indices the model includes carriage of goods by railway transport (*Trans_railw*) and highway transport freight turnover (*Trans_auto*) – independent in equations 8 and 9, correspondingly).

5. Intensification of highway and railway carriage of goods *(independent variables for equations 6, endogenous for the model – are defined in equations 8 and 9, correspondingly)* increases the increment of value added in transport sector in general (*VAdd_Trans*),

6. Indices of scenarios of *additional* volume of carriage of goods by railway and highway transport are preset within functions of normal distribution for variables *Trans_railw* and *Trans_auto,* correspondingly. In equations 11-18, the functions of normal distribution are explicitly presented for transportation by railway (equations 11, 13, 15, 17) and highway (equations 12, 14, 16, 18) transport, correspondingly. The availability of four scenarios, two of which are identical, is contingent on presence of two scenarios of distribution of investments at the prediction level, present in equations 3-6, correspondingly (two equations for each macro-scenario of investments accordingly).

7. A total amount of additional values added of transport ($Vadd\_Trans\_Total_{ij}$) depends on an additional volume of transportation by railway and highway transport within the region (independent variables within equations (19), but endogenous within the model, are generally determined in equations 8 and 9). Additional volumes are determined by scenarios present in 11-18, correspondingly.

8. An additional increment of GRP *(dependent variable in equation 20)* depends on the amount of additional added value of "transport industry" according to the preset scenario in a coordinate system "*i-j" (independent variable in equation 20, endogenous variable of the model is defined in equation 19).*

III. Results and Discussion

As it follows from the description of structural interrelations, as the indices of transport system performance influencing economic development (indicator – *index of physical volume of GRP*), are selected: *carriage of goods by railway transport (Trans_railw), million tons and highway transport freight turnover (Trans_auto),* million ton/km.

Therefore, according to specification in 1-8, the developed model consists of 20 equations, 12 of which preset the scenario parameters of distributions including – freight flow (equations 11-18), as well as investments (equations 3-6) for the relevant four scenarios.

The remaining equations (1, 2, 7-10, 19-20) include the parameters of distribution of investments and/or freight traffic volume and are interdependent within the framework of the equation system. The explicit form of equations of dependences, which logic is specified in 1-6 above, is obtained on a basis econometric simulation of relevant dependences over 2000-2016 based on data of the Russian Federal Statistics Service.

Thus, as a result of econometric analysis, the model is produced which represents a system of equations and individual variables preset by the normal distribution density:

It should be pointed out that interpretation of the key resulting equation (20), setting the power law dependence of additional increment of GRP on value added of the transport branch, meets the logic of current research of the impact of transport on economic growth. This type of function shows that the GRP sensitivity to transportation is nonlinear.

For the purposes of analysis of sensitivity of the Krasnodar Territory economy to a change in transport flows and, generally, to large-scale infrastructural changes due to construction of the Kerch Straight Bridge, we consider two scenarios presuming a change of three input parameters – indicator of physical volume of investments in basic stock, carriage of goods by railway transport, carriage of goods by highway transport.

For the forecast of the impact of infrastructure on the regional development rate we have to preset a distribution of exogenous variables, scenario conditions for prediction. In the context of the model under consideration, the scenario variables are *indicator of physical volume of investments in basic stock*, *carriage of goods by* railway *transport*, *highway transport freight turnover*. The range of distribution of values of the variable *indicator of physical volume of investments in basic stock* is built on the basis of the scenario of the Ministry of Economic Development [7]. A possible spread of values of indicators *carriage of goods by railway transport*, *highway transport freight turnover* is set on the basis of forecasts by the Ministry of Transport and Rosavtodor [8].

1. Scenario 1_1: "Increased increment of investments (increased risk) – conservative increment of transportation (reduced risk)".

This scenario assumes an increased increment of investments according to forecast [7, p. 6] (between 104.2% and 107.1%, values are distributed according to normal probability law) and a conservative growth rate of new transportation, which distribution parameters are estimated on the basis of forecasts by the Ministry of Transport [8]: on the horizon of bridge operation in the incoming years the carriage of goods may increase from initial 13 million tons to 16 million tons, while the freight flow across the Kerch ferry line is up to 10 million tons of goods. Therefore, it is fair to assume that within the first year of bridge operation the increment of freight flow will be 3 million tons, and with upside forecasts it will increase from year to year. However, stemming from the adopted conservative level, let's preset the distribution of increment of freight flow within the range of 3 to 4 million tons, in this case the ratio of railway and highway goods will remain at 1:3 which currently is typical for Krasnodar Territory. Therefore, the scatter band of indicator *railway transportation of goods* is from 0.75 to 1 million tons, for highway – from 2.25 to 3 million tons (values distributed according to normal probability law). Expressed in terms of highway transport freight turnover we get from 199.8 to 325.5 million tons/km (values distributed according to normal probability law). Distribution parameters for this scenario are given in equations (3), (11) and (12), correspondingly. As a result, the highest density of distribution of GRP (72%) is concentrated in the range of additional increment of 0.82% to 1.18%. The median increment value is 0.98%. It is worth noting that the coefficient of variation of increment of investments for this scenario is 0.005, while this indicator for alternative in terms of investment level scenarios (1_2 and 2_2) is 0.002. Thus, this scenario should be interpreted as the one which takes into account the increased risks of increment of investments at a high level of expected values. In line with similar logic, a level of risk for indicator the increment of transportation may be assessed as "reduced" relative to alternative in terms of this indicator scenarios (2_1 and 2_2, correspondingly): 0.046 versus 0.071 in case of railway transportation and 0.081 versus 0.098 in case of motor transportation.

2. Scenario 2_1: "Increased increment of investments (increased risk) – increased increment of transportation (increased risk)".

This scenario assumes an increased increment of investments according forecast [7, p. 6] (similar to Scenario 1_1) and an increased level of new transportation: contrary to the first scenario, the increment of carriage of goods will be from 4 to 6 million tons; for railway transport from 1 to 1.5 million tons, the freight turnover for highway transport – from 266.4 to 488.25 million tons km. Distribution parameters for this scenario are given in equations (4), (13) and (14), correspondingly. The highest concentration of distribution (69%) similar to Scenario 1_1 is concentrated in the range of additional increment of 0.82% to 1.18%. The median increment value is 1.01%. Similar to Scenario 1_1, with the high level of expected increment of investments, a higher risk of accomplishment is accounted for. In this case a level of risk for the indicator increment of transportation at a higher expected level is assessed as "increased" relative to alternative in terms of this indicator scenarios (1_1 and 1_2, correspondingly): 0.071 versus 0.046 in case of railway transportation and 0.098 versus 0.081 in case of carriage of goods by highway transport.

3. Scenario 1_2: "Conservative increment of investments (reduced risk) – conservative increment of transportation (reduced risk)".

This scenario assumes the conservative increment of investments according to forecast [7, p. 6] (between 102.7% and 104.2%, values are distributed according to normal probability law) and the conservative increment of transportation (similar to Scenario 1_1). Distribution parameters for this scenario are given in equations 5, 15 and 16, correspondingly. The highest density of distribution (74%) is concentrated in the range of additional increment of 0.80% to 1.19%. The median additional increment value of GRP will be 0.97%. The coefficient of variation of increment of investments for this scenario is 0.002, while a similar ratio for alternative scenarios 1_1 and 2_1 is 0.005. In this case a level of risk for increment of transportation, the same as in Scenario 1_1, is estimated as "reduced".

4. Scenario 2_2: "Conservative increment of investments (reduced risk) – increased increment of transportation (increased risk)".

This scenario assumes the conservative increment according to forecast [7, p. 6] (similar to Scenario 3) and the increased increment of transportation (similar to Scenario 2_2). Distribution parameters for this scenario are given in equations (6), (17) and (18), correspondingly. The highest distribution density (72%) is concentrated in the range of additional increment of 0.87% to 1.25%. The median additional increment value of GRP is 0.98%. Relative to scenario 1_2, this scenario is characterized by the reduced risk of increment of investments with a lower expected level, and compared to scenario 2_1 by increased risk of increment of investments with its higher level.

IV. Conclusion

In accordance with the produced scenarios the expected median values of the additional increment of GRP of Krasnodar Territory due to the increment of transportation associated with operation of the Crimean Bridge are in the range of 0.97% to 1.1%. The most conservative scenario presumes the median value of 0.97%; in this case with a probability of 74% subject to the most conservative scenario an additional increment of GRP will be within the range of 0.8% to 1.19%.

That said, the most optimistic scenario is characterized by a high risk of forecast accuracy in the highest concentration of distribution. A significant difference of levels of distribution concentration is caused by a nonlinear type of the key constraining equations: a corresponding deviation of the influencing factor brings about a higher deviation of the resulting variable ΔGRP which is aggravated by a chain of constraining equations.

The developed simulation model is an additional structure block of the regional generalized model described in [9], but can also be independently used for solution of narrow tasks, for example, for assessment of contribution of infrastructural investments in the increment of the gross regional product.

The development of the suggested simulation model can include additional constraining equations, more complicated non-normal distribution functions which use is justified as a "zero-order approximation" for assessment of effects in the context of limited data.

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