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The Public Efficiency Evaluation of Infrastructure Projects in Conditions of Modern Scientific and Technological Development

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Abstract. The infrastructure component of the scientific, technological and social development of Russia requires substantial elaboration of the methodology for appraisal of relevant investment projects in the direction of combining financial and economic analysis and evaluating various public effects, including social, indirect, price, tax, environmental and synergistic effects. The aim of the study was to develop an integrated approach to identifying and quantifying the gaps between financial and economic efficiency of different infrastructure projects and justifying the use of adequate mechanisms for their successful implementation.

The paper propose methods for estimating the public effects of infrastructure projects using three interrelated models: financial-economic, input-output multi-regional and econometric. By combining these models, it is possible to analyze the development trends of the global, national and regional economy in conjunction with the presentation of investment processes at the microeconomic project level. The proposed methods and models was tested in assessing the efficiency of five real infrastructure projects of various types and scales: the project of seven municipal clinics, the construction of the ESPO-2 pipeline, two core facility projects of catalysts and enzymes production, the complex of research infrastructure projects project in the Akademgorodok-2 program.

Keywords: financial and economic efficiency, budgetary efficiency, public effects, social and research infrastructure, public-private partnership.

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Общественная оценка эффективности инфраструктурных проектов в условиях современного научно-технического развития

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Аннотация. Статья посвящена методике оценки инвестиционных проектов научно-исследовательской и социальной инфраструктуры, совмещающей в себе финансово-экономический анализ и оценку различных общественных эффектов, в том числе социальных, косвенных, ценовых, налоговых, экологических и синергетических. Цель исследования заключалась в разработке комплексного подхода к выявлению и количественной оценке разрывов между финансовой и экономической эффективностью различных инфраструктурных проектов и обоснованию использования адекватных механизмов для их успешной реализации.

В статье предложены методы оценки общественных эффектов инфраструктурных проектов с использованием трех взаимосвязанных моделей: финансово-экономической, межотраслевой межрегиональной модели и эконометрической. Комбинируя эти модели, можно анализировать тенденции развития мировой, национальной и региональной экономики в совокупности с представлением инвестиционных процессов на уровне микроэкономических проектов. Предложенные методы и модели были апробированы при оценке эффективности пяти реальных инфраструктурных проектов различного типа и масштаба: проекта семи городских поликлиник, проекта строительства нефтепровода ВСТО-2, двух проектов основных объектов производства катализаторов и ферментов, а также комплекса проектов исследовательской инфраструктуры по программе Академгородок-2.

Ключевые слова: финансовая и экономическая эффективность, бюджетная эффективность, общественные эффекты, социальная и научная инфраструктура, государственно-частное партнерство.

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Introduction and Statement of the Problem

The successful implementation of infrastructure projects (IP), which are the core of modern scientific and technological development faces the problem of the lack of a generally accepted methodology that allows to quantify their impact on the economy of a city, region and country in terms of project analysis. As part of cost-benefit analysis (Economic Appraisal, 2021; Bonner 2022; Florio, Pancotti, 2022; Methodical recommendations, 2000; Novikova, 2022) appropriate methods of economic analysis are developed, which are used to evaluate projects not only in the public sector, but also in the private sector (Sunstein, 2018; Guidelines, 2017; OECD, 2019; Reference Case Guidelines, 2019; WECOOP, 2021). However, in practice, this direction of evaluating infrastructure projects was not broadly applied (Adler, 2012; Florio, 2021; Lucas, Montesinos, 2021; Dobes, at al., 2016). The assessment of the financial efficiency as the second direction of project justification has become the most widely used method of quantitative analysis in substantiating investment decisions. Until now, practice has been dominated by approaches to the evaluation of real projects in accordance with the financial project analysis.

This situation reflects the fundamental problem of analyzing the institutional structure of investment activity and choosing institutional forms for coordinating investment activity that ensure a combination of interests of direct project participants and society as a whole (country, region, city). This problem is most acute for investment projects characterized by a combination of low financial and high public efficiency and requiring implementation on the principles of public-private partnership (Yescombe, Farquharson, 2018; Infrastruktura, 2016; Malov, et al., 2016). These traditionally include infrastructure projects.

There is an urgent need to develop a modern methodology for quantifying the economic (in other words, public) efficiency of infrastructure projects and the possibility of timely assessment of risks caused by scientific and technological development. The aim of this paper was to develop an integrated approach to identifying and quantifying the gaps between financial and economic efficiency for infrastructure projects of various types and scales and justifying the use of adequate mechanisms for their successful implementation. For research infrastructure projects, this gap corresponds to the gap between academic and industry research, and the successful funding of innovations requires the use of public-private partnerships and the provision of government support, usually in the form of budget financing of investments in the creation of infrastructure facilities, as the leading mechanisms for increasing financial efficiency.

Both social and research infrastructure projects are characterized by high risks in conjunction with huge capital intensity, long payback periods and low return on investment. The corresponding low level of financial efficiency is not attractive to private investors. At the same time, the implementation of such projects leads to the emergence of additional effects associated with significant social, indirect effects and spillover benefits that are not taken into account on the market, but many times exceed in their significance the income directly received from the operation of infrastructure facilities and, ultimately, lead to an increase in national competitiveness and the growth of public welfare of residents in the respective territory. The

development and testing of a suggested methodology for calculating the economic efficiency with an assessment of costs and benefits from the point of view of the whole society makes it possible to obtain a reasonable forecast of changes in many interrelated indicators as a result of the project, including the level of social welfare, internal and external demand for manufactured products and services, the activation of investment activities due to the mutually beneficial interaction of various participants based on the objects being created. The aim of this paper is to develop an integrated approach to identifying and quantifying the gap between financial and economic efficiency of different infrastructure projects and justifying the use of adequate mechanisms for solving the problem of such gap through the use of an active government investment policy.

Until now, the evaluation of real projects has been dominated by of financial project analysis approaches that compare direct costs and benefits observed in the market and accompany the implementation of the project from the point of view of private participants.

A set of models
for evaluating infrastructure projects

The proposed integrated approach to the assessment makes it possible to qualitatively and quantitatively assess the interrelated consequences of the implementation of a separate infrastructure project, corresponding to the main public effects with a detailed presentation of the most important social, indirect, price and tax effects of this project. Another distinguishing feature of our approach is related to the analysis of the efficiency of participation in each project. To form effective workable mechanisms for project implementation, it is important to quantify the net benefits of various participants, and use the traditional cash flow approaches in project analysis for this. At the same time, the interaction of project participants acts as a redistribution of net benefits between various agents as a result of the relationship of their cash flows.

In this study, attention is focused on assessing the considered public effects using economic and mathematical tools that are adequate for each group of effects, which ensures higher reliability of information on costs and benefits and the resulting estimates of the efficiency of infrastructure projects.

Within the framework of this paper an original methodological and economic-mathematical toolkit is suggested for a comprehensive assessment of the efficiency of infrastructure projects and the efficiency of participation in these projects, based on the flexible combination of three groups of methods and models. First, the economic-financial model (EFM), which is based on project analysis methods, primarily cost-benefit analysis (CBA) (Novikova, 2022; Novikova, et al, 2020). Secondly, the optimization input-output multiregional model, which was proposed by A. Granberg and developed at the IEIE, SB RAS, Novosibirsk (Granberg et al, 2007) (OIMM) and the methodology for its application for evaluating large projects according to global criteria (Gulakova, Novikova, 2022). This model is used as the main tool for obtaining endogenous solutions at the macroeconomic and regional levels and calculating indirect effects. In addition, the model complex also includes an econometric model designed to conduct an endogenous marketing analysis of the project to obtain consumption forecasts in the intended sales markets and price effects (Suslov, et al, 2021).

The economic-financial model is used as a universal methodological base for evaluating all types of projects and is applied to calculate a system of comparable indicators of project efficiency and the efficiency of participation in the project. The last group includes the calculation of budgetary efficiency and the efficiency of participation for all investors, taking into account their changes as a result of the use of various forms of public-private partnership and government support.

The EFM is based on cash flows approach for project evaluation. The cash flows of the project describe the activity for its realization, irrespective of the sources of costs financing or the redistribution of revenues between various participants. The interrelationship between cash flows for different agents corresponds to each specific project implementation mecha-

nism, and these problems become decisive. The basic solution can be presented by the following equation that describes the interactions of various participants in a project in the form of interrelations between their cash flows and the efficiency indicators; specifically, all net present values:

$$NPV = \sum_{s} NPV^{s}$$

where NPV is net present value of the project, which is equal to NPV_F^s within the framework of financial efficiency analysis or equal to NPV_F^s within the framework of economic efficiency analysis. NPV^s is the net present value of the s-th participant of the project (NPV_F^s or NPV_E^s).

The information for the efficiency of a project is presented in the left-hand side of the equation, and the indicators for calculating the efficiency of participation in a project are in the right-hand side. The composition of participants and the corresponding cash flows are different within the frameworks of financial and economic efficiency analysis.

The positive net present value that arises after realization of an efficient project can be considered as a "pie," which is divided among the participants of a project by way of its financing. It provides sources for the efficiency of participation in a project. A significant positive net present value for each participant of a project would show that the financing scheme is of interest to participants and that the project will be successful.

Estimation methods differ significantly for various types of infrastructure projects. There are four main groups of factors for such a difference, related to the scale of projects, significant public effects, international environment, and the availability of initial information. Let's consider them in more detail.

The first group of factors is one of the leading ones and underlies the main classifications of infrastructure projects. Large-scale projects require assessment methods that are more focused on regional and national impacts than small local projects, respectively, requiring the use of two main models (EFM and OIMM).

The second group of factors is related to the internal characteristics of projects and is expressed in the different significance of certain public effects characteristic of each specific type of project. First of all, this is due to the difference in significant *social effects* for the projects of social infrastructure in compare with other types of infrastructure. Social effects are of particular importance for local municipal projects of social infrastructure and require a detailed multivariate definition, including using econometric methods. However, their impact, as a rule, is local, maximum regional. *Indirect and price effects* for relatively small innovation infrastructure projects, which are characterized by the main effects already at the first stage of use, are calculated as an increase in the quality and quantity of products in direct proportion to the implementation of the results of the project. For large-scale projects characterized by complex chains of input-output and multiregional relationships, it is proposed to endogenously determine indirect and price effects using OIMM and an econometric model. For large projects characterized by significant indirect effects, there is a difficult problem of their definition along the chain of inter-industry inter-regional relations. OIMM can be used as an economic and mathematical toolkit that allows endogenous calculation of these effects. The total value of indirect effects is determined by the decisions of the OIMM in comparison of options with and without the project based on changes in the final product and other macroeconomic, sectoral and regional indicators as a result of the project. *Environmental effec*ts generally occur in all projects, but on a relatively small scale. However, for individual projects, including small ones, they can be significant and require the development of special ecological blocks within the framework of the EFM. Tax effects are calculated in sufficient detail for all projects and, along with the difference in economic and financial efficiency, are included in budget efficiency. However, unlike ordinary private projects, in the case of infrastructure projects, most of them arise in the framework of economic rather than financial efficiency. In addition, econometric methods are used in the assessment of social

effects for infrastructure projects in the social sphere (Novikova, at al, 2022). Another group of *synergistic effects* can accompany the listed public, as well as financial effects. They arise in a complex of interrelated projects during their joint implementation. For example, when creating a center for the pilot production of catalysts, significant synergistic effects arise in terms of financial, indirect and tax effects of the project under consideration for the development of scientific and industrial infrastructure (Novikova, at al, 2020).

The influence of international economic factors differs markedly in different projects and is taken into account when forecasting import substitution and changes in exports. To evaluate large investment projects with significant foreign economic relations, a single set of models is formed, including the FEM, OIMM and the econometric foreign economic model (FEM).

The level of detail in project appraisal and the appropriate choice between a full evaluation and an express appraisal depends on the available capabilities and needs. Information capabilities often act as a starting point for evaluation due to the limited ability to obtain initial data about the project. The availability of baseline information and the need for a full detailed assessment are directly related to each other. In a number of cases, it is sufficient to conduct an express evaluation of infrastructure projects to make decisions. However, express assessment does not necessarily mean the use of extremely simplified assessment methods. It can involve the use of qualified expert estimates of model parameters in combination with the use of extensive information flows on the implementation of similar projects and forecasting the consequences of their implementation. For infrastructure projects in general, and especially for research infrastructure projects, quantifying net benefits is a difficult problem, and the application of express methods provides a solid basis for the overall preliminary assessment of such projects. The proposed methodology for such evaluation is based on the combination of two main models and allows you to get indicators of economic and financial efficiency as well as a variety of concrete effects both at the micro, and at the meso- and macroeconomic levels of analysis. It is especially important to apply such assessments to large-scale projects.

Despite all the differences, the projects under consideration unite belong to a certain infrastructure type, which requires the use of common methods for their assessment. These methods include a combination of economic and financial indicators, as well as the construction of adequate mechanisms for their implementation with a clear understanding of the participation of the government and business. Given the modern spread of the public-private partnership mechanism, the assessment of infrastructure projects requires the calculation and subsequent monitoring of redistribution processes between the main participants in PPP, including the assessment of participation in such agreements not only by the concessionaire and grantor, but also by banks.

Evaluating the economic efficiency only on the basis of economic and financial model

The project of 7 clinics. The use of methods for assessing social effects as part of the CBA is of particular importance for health development projects. These methods have been adopted to identify and measure their most significant consequences in monetary terms. The PPP project for the construction of seven polyclinics in Novosibirsk belongs to the flagship projects for the development of social infrastructure. The prices of 2018 were used as constant prices, and the initial data for the project were formed in accordance with the information at the time of the conclusion of the contract at the beginning of 2019 between the Ministry of Economic Development and the Ministry of Health of the Novosibirsk Region, on the one hand, and the private partner Seventh Concession Company, on the other hand. To assess the impact of medical expenses on economic growth, we used the method of budgetary social multipliers. In our experimental calculations, we rely on the estimates of the Center for Strategic Research (Kudrin, Sokolov, 2017) for the Russian healthcare budget multiplier equal to 1.25. At a 7.3 % discount rate, the project

generates a net loss of –1,741,602.4 thousand rubles as the size of financial NPV. However, the conclusions fundamentally change in the transition to assessing the economic efficiency of the project and taking into account its social and tax effects. At a 7.3 % discount rate, the NPV reaches the level of 12,966,953.1 thousand rubles, primarily due to social effects, which amount to 13,417,342.9 thousand rubles, i.e. their size exceeds the economic NPV by 3.5 %. In the context of changing directions and rising prices for the supply of imported medical equipment, both the financial and economic efficiency of the project decreased significantly, and in order to ensure a positive level of net present value for the concessionaire, the size of both investment and operating payments increased markedly.

The project of Catalysts Core Facilities. Approbation of project evaluation on the basis of EFM was although implemented for the projects of the Center for Collective Use Pilot Production of Catalysts (OPC) of the Institute of Catalysis SB RAS and the Center for Biocatalytic Technologies of the Institute of Cytology and Genetics of the SB RAS. Both projects are implemented within the framework of the program (enlarged project) "Academgorodok 2.0". For both projects, the dynamics of import substitution was set, corresponding to the baseline and mobilization scenarios.

The Pilot Production of Catalysts project was updated in comparison with the 2018 versions (Novikova, 2022). The main changes when adjusting the initial data were associated with a significant increase in prices. As a result of the initial calculation of the financial efficiency of the project at constant prices in 2018, it was determined that for the period 2019–2030, at a 12 % discount rate the project is characterized by a NPV (–505.9 million rubles) and cannot be implemented without government support. However, the determination of the economic efficiency of the project showed its high significance for the Russian economy (NPV of 197.7 billion rubles). Increasing the discount rate to 22 % results in a decrease in NPV of RUB 92.8 billion, still well above zero and the project's corresponding financial NPV of –916.1 billion RUB. The difference is explained by the presence of high indirect and tax effects for the Russian economy. The results of the project implementation are mainly used by enterprises of the petrochemical and oil refining industries, which are located outside the Siberian Federal District. With the transition to measuring the project at constant prices in 2022, all indicators increase noticeably, but their ratio does not fundamentally change. At a 22 % discount rate, the project is characterized by a negative financial NPV (–1,734.7 million rubles) and, at the same time, an exceptionally high economic NPV of 193.1 billion rubles).

The most significant contribution to economic efficiency comes from indirect effects that also occur in oil refining and petrochemistry. For the period 2029–2034, indirect effects at a 22 % discount rate are estimated at 149,066.4 million rubles (accounting for 77.0 % of the economic NPV) or 692,211.2 million rubles, when calculating by simple methods, without discounting (76.8 %, respectively). Under the conditions of the mobilization scenario, the volumes of production and sales of domestic catalysts increase significantly, while significant indirect effects arise in petrochemistry and oil refining, leading to a corresponding significant increase in the economic NPV of the project.

The project of Biocatalytic Technologies Center. An assessment of the project to create a Center for Biocatalytic Technologies at the Institute of Cytology and Genetics of the Siberian Branch of the Russian Academy of Sciences shows that the corresponding introduction of new enzymes and enzyme preparations for the period 2023–2034 will provide a significant economic net present value income in the amount of RUB 1,173,931.8 million. at a 17 % discount rate. Under the conditions of a pessimistic mobilization scenario, which provided for a gradual decrease in imports of enzymes and enzyme preparations, insulin and prednisolone to zero in the final year of 2034, the significance of the project increases even more: the economic NPV increases to 1,203,918.6 million rubles. at a 17 % discount rate, or 4,608,786.3 million rubles. calculated without discounting.

Evaluation of infrastructure projects using input-output multi-regional model

The ESPO oil pipeline project

Let's compare results of full and express evaluation on the example of the Eastern Siberia-Pacific Ocean (ESPO) oil pipeline project on the economy of the Russian Federation was obtained. The ESPO main pipeline system runs from the city of Taishet, Irkutsk Region, to the sea terminal located in Kozmino Bay, Vostochny seaport. The study analyzes the implementation of the ESPO-2 project, with a length of about 2,046 thousand km, the final part of the oil pipeline passing through the territory of the Far Eastern Federal District from the city of Skovorodino. Its construction began in 2010, and in 2013 the first tons of oil were pumped through the pipeline. The paper compares the results of the express assessment of the efficiency of the ESPO-2 project with the previously obtained assessment based on the full set of information.

The infrastructure project for the construction of an oil pipeline is inextricably linked with oil production. The construction of the "pipe" will allow in the future to increase production in the regions that serve as a resource base for the ESPO (Eastern and partly Western Siberia, as well as the fields of Yakutia) by the amount of the pipeline's throughput. Accordingly, in the express method for evaluating the effects of project implementation, it is necessary to take into account both the variables directly related to the pipeline construction project (sales of services and investments in construction) and the increase in oil production.

As a result of calculations using the express method, the magnitude of the indirect effect, measured in the growth of the final product as a result of the project in 2030, amounted to about 186 billion rubles, with a full assessment, this figure was close to 200 billion rubles.

Comparison of the results obtained in the framework of the full and express assessments revealed a relatively small error: no more than 7 % (Table 1). Thus, the accumulated net discounted income according to the express method as part of determining economic efficiency amounted to about 2.504 trillion rubles, which is approximately 6 % less than the same indicator obtained as part of the full assessment.

The budgetary efficiency in the framework of the express assessment turned out to be 3 % lower than its full assessment, and the financial one was 5 %. The payback period of the project in both options, due to its sufficient inertia, has not changed.

The structure of economic efficiency also remained practically unchanged (Fig. 1). For the Russian Federation, the sum of tax and indirect effects exceeds the financial efficiency of the project by more than 2 times.

Analysis of the results showed that the use of express assessment provides a comprehensive assessment of infrastructure projects, providing ample opportunities for obtaining a simultaneous assessment of the project at the macro-meso and micro levels of analysis.

Under given scenario conditions, express assessment gives an error in the range of 5–7 %, which makes it possible to use the proposed methodology for drawing up strategic development plans.

The Akademgorodok 2.0 project

As a result of approbation of the suggested methodology, an express assessment of the Akademgorodok 2.0 project was obtained.

Table 1. Comparison of key performance indicators expressed in net present value, RUB billion

Indicators	Express assessment	Full assessment	Error
Financial efficiency	361	377	5 %
Budget efficiency	457	471	3 %
Indirect effects	1 686	2 661	7 %
Economic efficiency	2 504	2 660	6 %

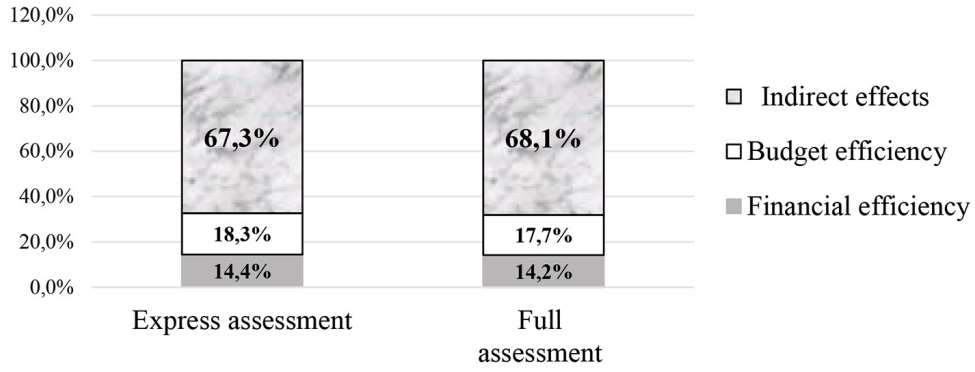

Fig. 1. Comparison of the structure of economic efficiency

Table 2. The main indicators of financial and economic efficiency for the projects. (billion rubles)

	Indicators	
	d = 7.3 %	d = 0 %
Financial efficiency (NPV)	-231.1	-189.8
Including tax effects	338.3	671.1
Indirect effects	693.9	1482.6
Economic efficiency (NPV)	801.1	1963.8
B/C	3.5	4.2
ROI	3.1	6.6
IRR (Financial)	-6 %	
IRR (Economic)	34 %	

The financial and economic efficiencies of the projects were estimated based on similar indicators. Table 2 shows the results of evaluating indicators for 18 years of project implementation at a 7.3 % discount rate.

Calculations of financial efficiency were carried out for the initial situation without budgetary financing. They show that the realization of all projects provided a negative NPV at a 7.3 % discount rate. Nevertheless, the result of estimations of the economic efficiency show huge positive indicators. The NPV, which was calculated at a 0 % discount rate within the frame of economic efficiency, exceeded the corresponding indicators of financial efficiency for the innovative multilateral project (by a factor of 7.8). The internal rate of return, within the frame of economic efficiency, also considerably exceeded the corresponding indicators for financial efficiency at the standard 7.3 % level.

Overall, an essential difference is seen between the financial and economic efficiencies. This forms the basis for government support being given to projects in the form of budgetary financing.

The assessment of the project under consideration was carried out within the framework of two main scenarios: the base one, corresponding to long-term relatively stable development trends with the traditional system of foreign economic relations, and the mobilization one, corresponding to a sharp increase in import substitution in order to ensure the country's economic security (Table 3).

The proposed model makes it possible to justify the need to intensify the government investment policy in the direction of supporting innovative import-substituting projects, taking into account not only the initial assessment of the system of project performance indicators,

Table 3. Economic efficiency of the project for basic and mobilization scenarios

Indicators	Basic scenario	Mobilization scenario
NPV, billion rubles, d = 7.3 %	801.1	3613.3
IRR,%	34	77
Payback period, years	7	5
ROI	3.1	14.1
B/C, d = 7.3 %	3.5	7.7

but also the formation of mutually beneficial mechanisms for coordinating interests based on quantitative assessments of redistributive effects, including not only within the framework of the financial efficiency, but also the corresponding economic efficiency of participation in infrastructure development projects.

As a result of the study, the hypothesis was confirmed about the critical impact of infrastructure development on the country's social and economic indicators and the need to create import substitution opportunities through the implementation of relevant scientific, technological and social infrastructure projects.

In general, due to the combination of the three models, it is possible to analyze the development trends of the world, national and regional economy in conjunction with the presentation of investment processes at the microeconomic project level, in particular, with the ability to calculate financial, budgetary and economic efficiency indicators traditional for evaluating infrastructure projects. The assessment of project performance indicators is supplemented by an analysis of the efficiency of participation in the project, which allows building adequate mechanisms for investment activities that ensure the interest of business in financing socially significant infrastructure projects, in particular, through their government support and PPP mechanisms.

Conclusions

Until now, practice has been dominated by approaches to the evaluation of real projects in accordance with the financial project analysis, which compares the direct costs and benefits that appear in the domestic market and accompany the implementation of the project from the point of view of private participants. This misses the opportunity of the economic aspect of the project analysis.

Suggested original methodological and economic-mathematical toolkit was created for a comprehensive assessment of the efficiency of infrastructure projects, based on the flexible combination of three groups of methods and models.

As an end-to-end toolkit for calculations, a financial and economic model of a separate infrastructure project was developed, which allows not only to simultaneously evaluate its economic and financial efficiency at the microeconomic level, but also to detail the application of various methods for assessing public effects for different projects. To obtain endogenous solutions at the macroeconomic, sectoral and regional levels, an optimization input-output multiregional model was used, which modified the initial version in two ways: by including or excluding the project. To obtain forecasts of prices and sales volumes in the world commodity markets, an econometric model was proposed, on the basis of which price effects was calculated.

Methods of project evaluation and corresponding models differ significantly for various types of infrastructure projects. There are four main groups of factors for such a difference, related to the scale of projects, significant public effects, international environment, and the availability of initial information.

The results of the study confirmed the fact that the simultaneous assessment of both the financial and economic of infrastructure projects and the efficiency of participation in these projects makes it possible to clearly identify strengths and weaknesses and create the basis

for their successful implementation in the face of modern global challenges.

The developed methods and models can be used as guidelines for assessing public effects for infrastructure projects of various types and scales. Based on the proposed approaches, a reasonable assessment of the economic and financial efficiency of real projects was obtained.

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