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INVESTMENT CAPACITY OF THE ECONOMY DURING THE IMPLEMENTATION OF PROJECTS OF PUBLIC-PRIVATE PARTNERSHIP

Abstract

The article considers the peculiarities of the mechanism of public-private partnership. An important problem of the research is to find an optimal ratio in the investment distribution when the arising positive externalities are maximized. In the critical literature review, the assumption was made that the balance between the market and state methods of regulation allows reaching the sustainable growth from the point of view of the use of resources. This hypothesis is developed in the analysis of the multiplicative effect through the index of GDP investment capacity. The research approach is based upon the study of the regression dependencies: multidimensional optimization is solved by the method of configurations with performing the iteration procedure. The obtained results show that the state contribution into the total investment potential of the projects of public-private partnership is traditionally low. The maximal investment capacity of the economy can be reached when maintaining the structure of investment distribution at the ratio 0.09/0.91 for the public and private sectors, respectively. The practical use of the optimization model allows to introduce the flexible mechanism of coordination of the terms of project financing.

Keywords	public-private partnership, multiplicative effect, investment capacity of the economy, market failure, state failure, infrastructure projects
JEL Classification	E22, G11, H54

INTRODUCTION

In the modern world, the public-private partnership (PPP) is an efficient tool of economic development. The significance of partnership as one of the most important investment mechanisms is determined by the necessity to maintain the required level of infrastructure provision at the limited resources (Postnikova, 2017). In this regard, the state faces a strategically difficult problem of creating favorable climate and conditions when the investments used will maximize the positive externalities. Therefore, the subject of this research is the investment capacity of the economy when implementing the projects of public-private partnership. The optimal ratio of the investment distribution becomes an important issue.

A balanced cost structure provides the obtaining of wider advantages from investments, creating favorable prerequisites of the sustainable innovation development that is a fundamental factor of economic growth. This explains the widespread distribution of the mechanism of public-private partnership. It should be mentioned that the innovation development cannot be completely connected to the state par-

ticipation; it should be made mainly due to the demand formation from the private sector of economy. Reasonable proves of this position are shown in the result of the research when analyzing the distribution of investments.

The offered approach is based upon the study of regression dependencies between the gross domestic product (GDP) and a specific share of public and private investments. The model solves the problem of maximization of GDP investment capacity from the multiplicative participation. The involved problem here is the necessity to stimulate the processes providing the functional efficiency of PPP. Therefore, it seems reasonable to consider the genesis of public-private partnership in a short literature review.

1. LITERATURE REVIEW

In the economic literature, the inefficient use of the private sector is determined as market failure. In the modern conditions, the companies have limited possibilities to use the internal capacities and the main source of their growth is a synergy effect of the partner cooperation. The use of methods of state regulation allows to decrease such negative effects. The active state participation creates new companies. The duality of the situation is explained by the risk of formation of the symmetrical effect, that is, the state failures that can cause the strong uncertainty of the system.

The general economic reasons of the exogenous and endogenous effects such as instability and imperfection of competitiveness (Howard, 2001) are the basis of the market failures, as well as the incapability of the market to satisfy the demand for the public good (Howard, 2001); asymmetry of information between the participants of the market (Moroney & Krysik, 1998); uncertainty of the environment (Moroney & Krysik, 1998), etc. Many interpretations of the "market failure" handle the efficiency of use of the available resources, in particular: inability to provide the optimal use of resources according to Pareto (Yakobson, 1996); costs of market coordination and its imperfection lead to the situation when the resource is used inefficiently (Pankratov, 2010). Thus, summarizing the definitions we can specify that market failure is an institutional position when the market form of business activity is not able to settle the contradictions between the economic agents. Kapkanschikov (2009) shares the same opinion specifying that the disadvantage or market failure is a situation when the market mechanism cannot provide the optimal allocation, efficient and fair use of resources and in this context, the role of the

state as a general manager is to correct such market failures.

At the same time, the reasons of formation of the market failures are rather diversified. According to the public choice theory, they are determined by the following distributed factors (Platonov et al., 2008): limitation of information; failure to control the counterparts properly; low quality of provided collective and individual public good; bureaucracy; duplication of functions, etc. The transformation of factors and reasons of "failures" is connected to the genesis of the essence of state, the change of the functions assigned by the society (Kushlin, 2005) that leads to the conclusion that the state and market are not the perfect institutions, and failures are an integral part of the evolutional development (Arkhipova, 2010).

The optimal ratio between market and state methods of regulation allows to achieve the sustainable development from the point of view of the resources use. At the same time, the maximally efficient development is understood as the state of the economic mechanism when the "excessive" transaction costs are neutralized (Kuzmin, 2012) (transaction costs above the normal level), which is provided by the developed infrastructure and the harmonized institutional environment. The search of balance predetermined the choice of the state private partnership as an adequate solution of the system failures to provide the economic growth (Vries, 2013).

The historical aspect of partnership of the state and business is rather well described in the scientific literature. The accumulated experience of research of the partner model characterizes it as the least studied one from the point of view of the structural organization. The grounded choice of

the model makes it necessary to study the mechanism of its practical realization.

According to Postnikova (2017), the public-private partnership is a combination of the forms of medium- and long-term interaction for solving the socially significant problems on mutually beneficial terms. From the time aspect point of view, such approach is reasonable, but it requires the concretization of forms and time limits of PPP, and besides, it is necessary to establish the limits of responsibility between the participants. In the opinion of Bures (2017), PPP is used in a wider sense and means any contract or legal relationships to improve and/or enlarge the range of infrastructural services excluding the state orders (government procurements).

Based on the objective, 4 groups of notions of public-private partnership can be distinguished: institutional (Varnavsky, 2004), contractual (Delmon, 2009; Akitoby et al., 2007), process (Makhortov & Semchenkov, 2007) and resource (Kolesnikova, 2008). The classification of notions according to the terminological groups reflects the main definitions and demonstrates the diversity of approaches.

The necessity of cooperation of PPP is determined in the works of Turovsky (2017). The similar ideas are traced in the research of Merzlov (2015) who notices that the application of PPP in comparison

with the public investments is the only possible variant of the breakthrough growth of competitiveness of the region. However, the problem of efficiency estimation of the measures when implementing the joint-venture projects is to agree the interests of parties that set rather conflicting objectives (Rybasova & Krasova, 2016; Seeletse, 2016). Here the concept of Lavlinskii, Panin, and Plyasunov will be interesting, which says that PPP is a form of a compromise of interests between the participants (Lavlinskii et al., 2016). It is expressed in attracting investments into the real sector of economy and facilitating of entrance to the market for capital. The point of view of Gugkaeva and Tuaeva deserves attention; they offer to consider PPP from the position of the rational use of the public resources that are the base of quality improvement of the factors of production that are used to transfer to the long-term and qualitative economic growth (Gugkaeva & Tuaeva, 2017).

The development of the functioning mechanisms of partnership gives new efficient methods of financing (Benito et al., 2008; Rajanet al., 2009). At the same time, the relations of ownerships are changing significantly. The reformation of ownership relations requires not only the grounding of the mechanism of introduction of new forms of business activity, but also the forecasting of the future changes.
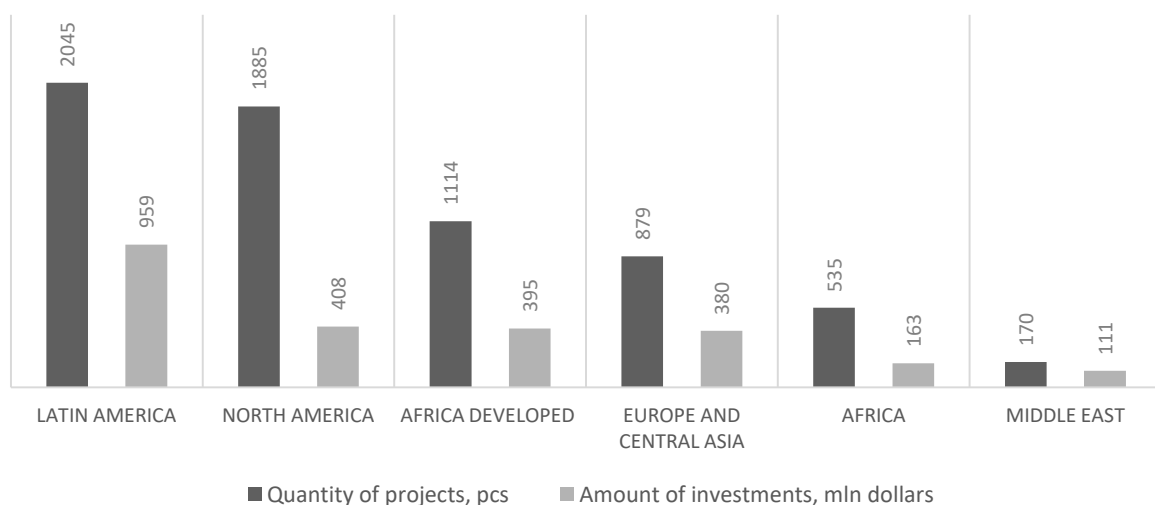
Source: World Bank Open Data.

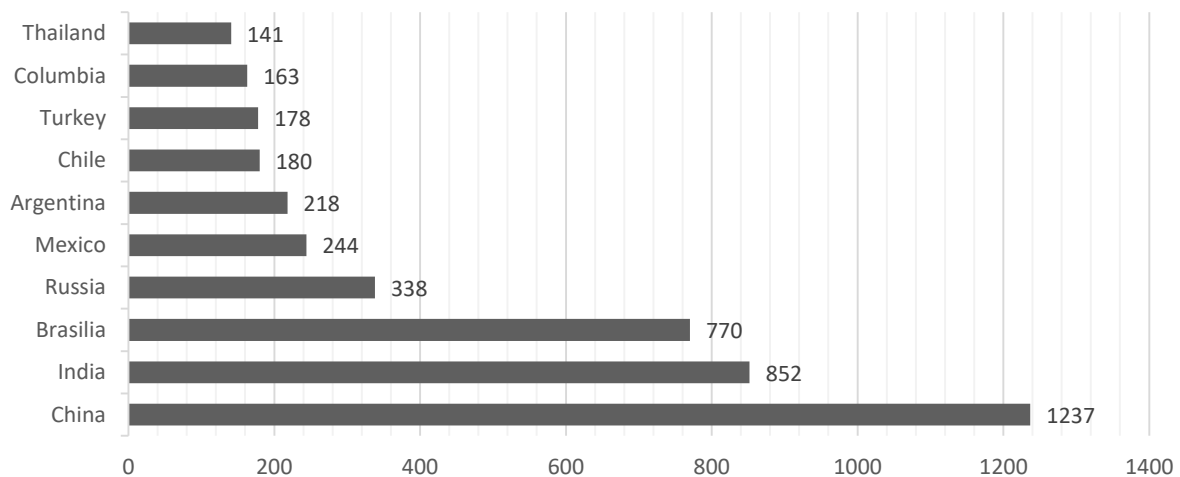**Figure 1.** Infrastructural PPP projects for 1990–2017

Figure 2. Top-10 countries using the PPP mechanism, number of contracts

2. ANALYSIS OF MACRO TENDENCIES

The world experience of implementation of projects of public-private partnership shows that such system is actively used in developed economies. According to the research performed by the World Bank (n.d.), there are about 6,628 PPP projects for the total amount of 2.4 bln dollars of investments. The number of contracts and the volume of investments into PPP projects for the studied period are shown in Figure 1. A positive tendency is observed to increase the number of projects implemented on the basis of PPP.

Thus, the countries of Latin America and the Caribbean take the first place according to the number of PPP projects. The most active countries in this region are Columbia, Chile, Mexico and Brasilia that obtain about 77% of investments into the region. A share of the projects in Europe and Central Asia in the total world index is less and estimated at the level of 13%. On the whole, according to the provided data, we can observe the positive tendencies of the development of PPP projects in the world. According to the estimations, the annual global investments into infrastructural projects are on average 2.5% of the world GDP.

The total statistics of the top-10 countries according to the volumes of the implementation of PPP projects is shown in Figure 2. Where analyzing

profoundly the public-private partnerships in the countries that differ by their accelerated growth of GDP at the level of 3-6% per year, we can conclude that China is the most active country according to the number of projects. The most dynamically developed field is a project financing of production.

When studying the investment flows, we can conclude that the system has a heterogeneous structure and needs balance equilibrium. This is a key aspect of the work. Considering the process of solution of the optimization problem, it is reasonable to mention that it is based on the development of the mathematical model and calculation experiment. We shall address the description of the method of the optimal ratio of the investment distribution for maximization of the function of GDP investment capacity.

3. MATERIALS AND METHODS

The basis of the econometric model of estimating the efficiency of using the format of public-private partnership is a regression analysis that shows the dependence of the GDP growth on the changes in the structure of the project financing. The method solves the problem of maximization of the GDP investment capacity from the multiplicative participation of the public and private sector. This offers exciting possibilities not only

Table 1. Dynamics of changing of GDP investment capacity and a share of state participation in the financing of the EU investment projects

Index	2008	2009	2010	2011	2012	2013	2014	2015	2016
GDP investment capacity (volume of capital investments to GDP), %	20.6	22.7	25.9	25.2	27.4	30.9	28.6	21.1	24.8
Investments of public sector, % of GDP	2.4	3.0	4.3	2.7	2.9	3.1	4.1	2.6	3.4

in the field of determination of the optimal ratio in the investment distribution, but also in their control as regulating parameters of the system. The information basis of modeling is the time series for 2008–2016 representing the EU economy state shown in Table 1.

Analyzing the data from Table 1, it should be mentioned that the indexes were changing in different directions and, at the same time, the trends of cyclicity of the GDP investment capacity and the shares of investments of the public sector were almost the same. This is explained by the priority of influence of the private sector on the general level of investments into the EU. The exclusion of repetition of the index dynamics was only 2012 when the value of the share of public investments into GDP reached its historical maximum and a share of private investments on the contrary decreased. For the objectives of the research, it should be mentioned that the interconnection between the parameters is significant and sufficient for the continuation of the correlation and regression analysis.

Within the frameworks of the model, the following algorithm is supposed to be executed:

1) selection of the approach of the unconditional multidimensional optimization – configuration method that allows to simplify the process of extremum seeking of the objective function as the function of many variables;

2) formalization of the objective function in the form of dependences of the GDP investment capacity on the shares of the public and private sector in the total volume of investments;

3) determination of the basic conditions of realization of the configuration method for optimization of the objective function;

4) stage-by-stage iteration procedure of realization of the configuration method and finding of iteration to which the maximum value of the GDP investment capacity of the public and private sector correspond.

The statement of the optimization method will be performed using the following symbols: y – GDP investment capacity (IC), %; x_1 – investments of the private sector (PI), % of GDP; x_2 – investments of the public sector (SI), % of GDP. The coordination directions of optimization of the objective function shall be set in the form of $s_1, s_2, \ldots, s_n$. We shall choose the corresponding level $\varepsilon > 0$ of the allowable value of accuracy of the obtained result to stop the realization of the algorithm. Besides, we set the initial step of the algorithm $\lambda > 0$ for transferring from one iteration to the next one and correcting of the variable values of control and also the value of the accelerating factor $\alpha > 0$ for seeking the optimal value in the necessary direction.

After fixation of the initial parameters, we choose the initial base point $X_1 = \left(x_1^1, x_2^1, \ldots, x_n^1 \right)$ of numeric values of the factor indications of the functional dependence in the form

$$f(IC) = a + m_1 PI + m_2 SI + m_3 PI^2 + + m_4 SI^2 + m_5 PI^3 + m_6 SI^3, \tag{1}$$

and get to the main calculations, presupposing that $Y_1 = X_1$, $k = j = 1$. The grounding of the function type (1) is based upon the analysis of the information base of modelling of the public share in the financing of PPP projects that showed the maximum criterion of determination at the level of 92% with respect to the third-order polynomial.

Stage 1. If the condition is fulfilled, the mathematical formalization has a form of

$$f\left(Y_j + \lambda s_j\right) < f\left(Y_j\right). \qquad (2)$$

This step can be considered successful. In this case, it is necessary to go to the next stage.

If the condition (2) is fulfilled, then this ratio becomes as in equation:

$$f\left(Y_j + \lambda s_j\right) \geq f\left(Y_j\right). \qquad (3)$$

and the current step can be determined as unsuccessful. In this case, it is necessary to check additionally the fulfillment of the next condition:

$$f\left(Y_j - \lambda s_j\right) < f\left(Y_j\right). \qquad (5)$$

If the ratio (5) is correct, you shall go to the second stage, introducing the assumption:

$$Y_{j+1} = Y_j - \lambda s_j. \qquad (6)$$

Otherwise, when fulfilling this condition:

$$f\left(Y_j - \lambda s_j\right) \geq f\left(Y_j\right), \qquad (7)$$

it is necessary to perform a gradual transition to the second stage and presuppose that:

$$Y_{j+1} = Y_j. \qquad (8)$$

Stage 2. If $j < n$, it is necessary to go back to the first stage, introducing the substitution of j for $j+1$. In case of non-fulfillment of the provided condition, we shall go to the next third stage provided that the in equation is fair:

$$f\left(Y_{n+1}\right) < f\left(X_i\right). \qquad (9)$$

Otherwise, we shall go to the fourth stage when fulfilling the condition:

$$f\left(Y_{n+1}\right) \geq f\left(X_i\right). \qquad (10)$$

Stage 3. We shall introduce the assumptions:

$$\begin{aligned} X_{k+1} &= Y_{n+1}, \\ Y_1 &= X_{k+1} + \alpha\left(X_{k+1} - X_k\right). \end{aligned} \qquad (11)$$

We go to the first stage, introducing preliminary $j = 1$ and replacing k for $k+1$.

Stage 4. If the condition $\lambda \leq \varepsilon$ is fulfilled, this fact confirms the completion of calculations, that is, X_k becomes a solution of the optimization problem. Otherwise, when non-fulfilling the condition it is necessary to replace λ for $\lambda/2$, and also to introduce this assumption:

$$Y_j = X_k, X_{k+1} = X_k. \qquad (12)$$

After realization of the mentioned actions, it is necessary to return to the first stage, having accepted $j = 1$ preliminary and having replaced the value k for the value $k+1$.

4. RESULTS AND DISCUSSION

4.1. Functional dependence

The data from Table 1 are the basis for realization of the first stage of provided algorithm. As it was mentioned earlier, the analysis of the statistical basis of modelling points out the necessity of use of the regression dependence by the third-order polynomial as the adequate characteristics (the criterion of determination is at the level of 92%). Based on this, we shall turn to the realization of the model using the set statistical data (Table 2).

The obtained interdependencies of the GDP investment capacity and the impact of the public investments when financing PPP projects are reflected in the multifactor non-linear equation

$$\begin{aligned} IC = &128.92 - 20.36PI + 17.31SI + \\ &+1.03PI^2 - 5.64SI^2 - 0.02PI^3 + 0.68SI^3. \end{aligned} \qquad (13)$$

The equation (13) determine the low significance of the investment parity. The analysis shows that when the threshold level of 20% share of the pri-

Table 2. Statistical basis of modelling

Period	y	x1	x2	x12	x22	x13	x23
2008	20.6	17.8	2.4	316.8	5.8	5,639.8	13.8
2009	22.7	19.0	3.1	361.0	9.6	6,859.0	29.8
2010	25.9	16.9	4.3	285.6	18.5	4,826.8	79.5
2011	25.2	20.0	2.7	400.0	7.3	8,000.0	19.7
2012	27.4	21.9	2.9	479.6	8.4	10,503.5	24.4
2013	30.9	23.8	3.1	566.4	9.6	13,481.3	29.8
2014	28.6	20.2	4.1	408.0	16.8	8,242.4	68.9
2015	21.1	17.2	2.6	295.8	6.8	5,088.4	17.6
2016	24.8	18.9	3.4	357.2	11.6	6,751.3	39.3
Average values	25.2	19.5	3.2	-	-	-	-

vate investments in the total volume of financing is exceeded, there is a multiplicative effect. The prevailing of the public sector of the economy is specified at the level of 17%. In general, the possibility to decrease the investment capacity of the economy is traced at the significant lag of the step of 5.6%. The main structure of the investments means, first of all, formation of the import phase-out component of production. Due to this, there is a need in the gradual development of the branches that allows to increase the capital consumption. The projected statistics of the time lag at the level from 0.14 to 0.22 shows that a share of less than 25% of the private capital cannot form the strategic direction when implementing the projects of public-private partnership.

4.2. Iteration of optimization model

We shall perform the maximization of the objective function on the basis of the configuration method provided that the corresponding values are achieved by the control variables. We shall set the coordination directions of the objective function optimization and offer the following assumptions: $\varepsilon = 0.001 > 0$ (the allowable level of accuracy of the obtained results to stop the realization of algorithm); the initial step of algorithm $\lambda = 0.2 > 0$ for transferring from one iteration to the next one and correcting the variable values of control (investment shares of the public and private sectors in PPP projects financing); the value of the accelerating factor $\alpha = 0.5 > 0$ (seeking the maximal value of the GDP investment capacity). The initial base point is set on the base of statistic regression model $X_1 = (20.72; \ 3.36)$.

It should be taken into account that the classic setting of the optimization problem presupposes the necessity of the reverse minimization of index selected as a resulting factor. Therefore, when solving the problem of maximization of the GDP investment capacity due to the achievement of the optimal ratio of the investment shares of public and private sector in the financing of PPP projects, it is necessary to change the signs in equations.

Iteration 1 ($k = 1$). As the condition is fulfilled, the mathematical formalization is $f\left(Y_j + \lambda s_j\right) < f\left(Y_j\right)$, this step can be determined as unsuccessful. In this case, it is necessary to perform the gradual transition to the second stage and presuppose that $Y_{j+1} = Y_j$.

Iteration 2. As $j < n$, it is necessary to return to the first stage, introducing the substitution of j for $j+1$. In case of non-fulfillment of the provided condition, we shall go to the third stage when the in equation is unfair $f\left(Y_{n+1}\right) \geq f\left(X_k\right)$.

Repeated iteration 2. We shall offer an assumption $X_{k+1} = Y_{n+1}$, $Y_1 = X_{k+1} + \alpha\left(X_{k+1} - X_k\right)$. We go to the first stage introducing preliminarily $j = 1$ and having substituted k for $k = 1$.

In a similar way, we will perform some intermediate calculations until we obtain the optimal value (Table 3).

Iteration 20. If the condition $\lambda \leq \varepsilon$ is fulfilled, this factor confirms the completion of calculations, that is, X_k is the solution of the optimization problem.

Table 3. Iteration procedure of optimization

k	λ	$\dfrac{X_k}{f(X_k)}$	j	$\dfrac{Y_j}{f(Y_j)}$	s_j	$\dfrac{Y_j + \lambda s_j}{f(Y_j + \lambda s_j)}$	$\dfrac{Y_j - \lambda s_j}{f(Y_j - \lambda s_j)}$
1	0.20	19.52	1.00	19.52	1.00	19.72	-
		3.18		3.18	0.00	3.18	
		24.55		24.55		24.85	
			2.00	19.72	0.00	19.72	
				3.18	1.00	3.38	
				24.85		25.29	
2	0.20	19.52	1,00	19.72	1.00	19.92	19.52
		3.18		3.38	0.00	3.38	3.38
		24.55		25.29		25.59	25.00
			2.00	19.72	0.00	19.72	19.72
				3.18	1.00	3.38	2.98
				24.85		25.29	24.47
				<…>			
19	0.20	24.32	1.00	24.52	1.00	24.72	24.32
		2.58		2.78	0.00	2.78	2.78
		30.52		31.09		31.29	30.87
			2.00	24.52	0.00	24.52	24.52
				2.58	1.00	2.78	2.38
				30.74		31.09	30.37
20	0.20	24.72	1.00	24.92	1.00	25.12	24.72
		2.78		2.98	0.00	2.98	2.98
		31.29		31.83		32.00	31.64
			2.00	24.92	0.00	24.92	24.92
				2.78	1.00	2.98	2.58
				31.48		31.83	31.14

Taking into account the preliminary tendencies of its formation, the implementation of the offered method allowed revealing that the maximal level of the GDP investment capacity is 31.29%, among which 2.78% are the public investments, and 24.72% are the private sector. At the same time, the residue that is 3.79% of the GDP investment capacity is formed at the expense of other sources (factors). Taking this into account, the maximization of the GDP investment capacity can be achieved by determining the share of public participation when financing PPP projects in the amount of 8.88%, and the private sector – 91.12%, respectively.

CONCLUSION

Investments play an important role in the economic growth. It becomes evident that the existing structure of investments does not correspond to the necessity of formation of the maximal investment capacity of economy. The analysis showed that the public contribution in the common investment potential was traditionally low, which complies with the conclusions of the research. However, the search of the efficient balance leads to the review of the strategic role of the state. The offered approach allows finding the preliminary solution of this problem and determining the optimal proportion of the investment distribution when financing PPP projects. The obtained results allows concluding that the provision of the GDP maximal investment capacity can be achieved when maintaining the structure of distribution of the participation at the ratio 0.09/0.91 for the public and private sectors correspondingly at the set example of the experimental approbation. At the same time, the private financing of the public infrastruc-

ture contributes to the risk transfer from the state. In these circumstances, the analysis of the nature of the risk formation of PPP projects, and the selection of the methods of their estimation and control are important. On the other hand, the change of ratio in the investment structure shall be considered in the context of the key factors of efficiency for every participant in the project. The practical use of the optimization model allows introducing the flexible mechanism of the conditions agreement of financing of the projects of partnership. The further research of the problem shall be focused in the field of the simulation modelling for the complete proof of the obtained results.

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