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Operations research applied to attracting investments in agro-industrial complex

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The possibility of computer simulations application is argued to satisfying the information demand of investment portfolio risk analysis in the cases when the shares of interrelated real investment projects are included in the portfolio. A complex of cash flow simulation model and portfolio simulation model is developed that makes it possible to approach statistic characteristics of economic effect of investment projects and estimate expectation value of investments in real projects in the presence of governmental support. The empirical base of the model consists of the project feasibility study materials, data on project-specific prices variation and aggregated price indices. The instrumental methods, based on the proposed model, allow making decisions about capital investment as well as about forms and amount of state support aimed at improving investment attractiveness of the agro-industrial complex.

Keywords: investment risk estimation, portfolio investments, cash flow, investor's behavior, Markowitz model. computer simulation.

Introduction

A weak point of risk management in Russian agro-industrial complex is that the demand for information does not commonly meet the sufficient supply. The nature of this feature is dualistic. On one hand, risk management applications of the data available from regular accounting and statistics, if possible at all, often requires either developing original approaches or even special research. On the other hand, as the risk manager has made a decision on data sets to use, a lack becomes evident of algorithms and, a fortiori, software that suit to these specific data.

The scope of the study presented in this paper is the above mentioned weakness, limited to the case of making decisions aimed at optimizing investors' risk so to make a specific investment area (agro-industrial complex in our case) more attractive. The toolset we develop allows a risk manager to satisfy substantial part of their information demand using reachable data and uniform algorithms.

Specifications of an information system aimed at risk analysis of investment projects are based on the analyst's demand for information. The practice of making investment decisions suggests that the essential economic dimensions of a project are the net present value (NPV) of the cash flow resulting from the project and the internal rate of return (IRR), which, providing acceptable reservations, indicates the relative efficiency of the invested capital [4, p. 299-300]. Providing that the data on the stochastic

properties of project parameters are available, an opportunity arises to simulate variational series of both NPV an IRR. As soon as such series are obtained, the indicators can be assessed that are commonly used in project risk management, such as net present value at risk, expectation value of NPV, probability of negative value of NPV, variance of IRR, correlation between IRRs of different projects exposed to the same stochastic factors.

For the purpose of satisfying the demand for information that emerges due to project analysis needs, computer simulation can be applied. Specifically, A. Bykova [1] elaborates the methodology of computer simulation of project cash flows. However, the framework of [1] is not sufficient to meet the demand for information that emerges in the case of combining real and portfolio investments. Our paper is aimed at developing a framework of computer simulations such that the projects exposed to the same risk factors could be analyzed simultaneously. We believe that this framework can be used by various participants of project analysis procedures:

1) it enables an analyst to perform a complex evaluation of project risks in interconnection with effect of simultaneous implementation of other projects;
2) it helps an investor to reasonably include real investment shares in the investment portfolio considering interrelations between risk and profitability of different projects and securities;
3) it enables a researcher to simulate investors' behavior in the capital market, particularly in order to substantiate the efficiency of governmental policies aimed at capital attraction.

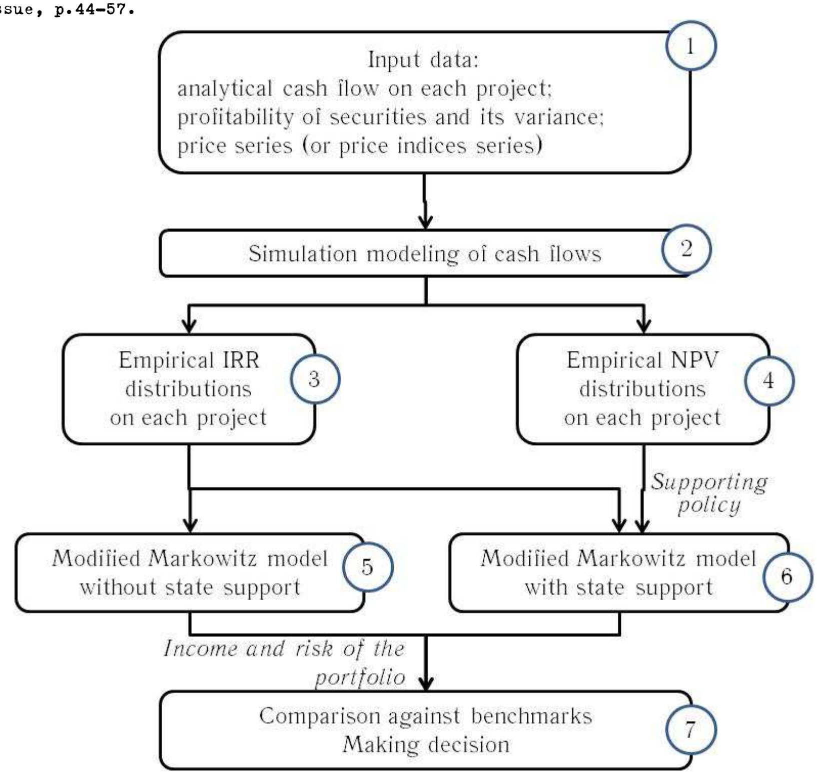
Methodology

In connection to above mentioned role of the analytical framework we develop, the demand for specific information should be met:

1) of the analyst: in the expectation value of NPV, variance of NPV, and probability of negative NPV;
2) of the investor: in the expectation value of IRR, variance of IRR, probability of IRR lower than the opportunity cost of capital (which is equal to the probability of negative NPV), and correlation of IRR of different projects, which is necessary to minimize the risk of the portfolio;
3) of the researcher: all the data demanded by both the analyst and the investor.

Picture 1 below presents the aggregated view of the analytical process that generates the demanded data.

The basic formal framework of modeling investor's behavior is the classical model of investment portfolio developed by H. Markowitz [6]. Despite important limitations [2], the formalism based on this model covers a wide range of important practical cases.



Pic. 1. Chart of information flows facilitating simulation of an investor's behavior in presence of governmental financial support

For the purpose of our study, we extend the Markowitz model with variables that denote shares of the capital stock invested in real sector projects. The normality of distribution of each project's IRR is essential for the validity of such extended model. It should be tested prior to its composition. The complete model is defined as follows:

$$\begin{aligned}
&\min_{x_i,\, i\in I} \frac{1}{2}\sum_{i\in I}\sum_{j\in I} r_{ij}\sigma_i\sigma_j x_i x_j,\\
&\sum_{i'\in I'}\mu_{i'}x_{i'} + \sum_{i''\in I''}\mu_{i''}x_{i''} = \bar{\mu},\\
&\sum_{i\in I} x_i = 1,\\
&b x_{i''} \leqslant c_{i''},\ i''\in I'',\\
&x_i \geqslant 0,\ i\in I,
\end{aligned} \qquad (1)$$

where I' is a set of securities with normally distributed income; I'' is a set of real projects with normally distributed IRR; I is $I' \cup I''$; x_i, x_j, $x_{i'}$ and $x_{i''}$ are the shares of the corresponding (i^{th}, j^{th}, i'^{th}, i''^{th}) security or project in the portfolio, providing that $i \in I$, $j \in I$, $i' \in I'$ and $i'' \in I''$; r_{ij} is Pearson's pairwise linear correlation coefficient between the normalized income from the i^{th} and j^{th} security or project; σ_i and σ_j are standard deviations of the normalized income from the corresponding securities or projects; μ_i is the expectation value of normalized income from i^{th} security or project; $\bar{\mu}$ is the target expectation value of normalized income from the portfolio; b is a total worth of the portfolio; $c_{i''}$ is a present value of the total project cost of project i''.

For the members of I'', the expectation value of IRR, its standard deviation and correlation coefficients are derived from the simulated project cash flows. Following the approach developed in [1], one has

$$CF_{pk} = x_{p1k} - \sum_{f\in F\setminus\{1\}} x_{pfk},$$

where $p \in P$, $k \in K_p$, $f \in F$; K_p is a set of time periods that covers the lifetime of project p; F is a set of cash flow components, which consists of 1 for revenues, 2 for material costs, 3 for managerial costs, 4 for labor costs and 5 for taxes; x_{pfk} is a value of f^{th} component of the cash flow generated by project p in the period k; P is a set of projects under consideration.

Each f^{th} component of a cash flow can be thought about as a time series consisting of random values. The final judgment on the project risk depends on each of these values. In this respect, computer simulation of the project cash flow requires information about statistic distributions of each value in each time series. We restrict our study with two cases of distribution laws: normal and gamma.

The normal distribution is the most common, as it emerges in every probabilistic situation where Lyapunov's central limit theorem holds. As far as under the normal distribution the probability of any negative value is strictly non-zero, this distribution can at best approximate the empirical distribution of cash flow components, which are all non-negative in reality. A. Orlov writes in [7] that a maintainable model of a true statistic distribution of demand on some commodity is commonly the gamma distribution. Assuming that some vicinity of actual demand is characterized by (nearly) linear relation between demand and price, the probability distribution of this price is also gamma. Insofar, even in case of absence of empirical evidence of a specific distribution of cash flow components, we can rely on the theoretical judgment in our belief that cash flow components representing costs are distributed according to gamma law in case *when the in-kind project purchases are fixed*. The same extends to revenues in case when the sales in kind are fixed. Following this reasoning, we hereafter accept the rather restrictive assumption that amounts in kind the project deals with are certain, while prices are stochastic.

The parameters of the normal distribution are the expectation value and standard deviation of the random value. As for the gamma distribution, its parameters are functions of the same moments. In presence of risk, the values of cash flow components that are found in business plans are commonly thought about as expectation values. As for standard deviations, none of their proxies can normally be found in business plans, with rare exceptions. As for now, the only general way to fill this gap in information base of project risk management is computer simulations.

Following the above made assumption about certainty of non-price sources of cash flow components' variation, calculation of standard deviation of each component in a specific time period is based on:

- either price time series or price variance data in case of a cash flow component that is caused by the single commodity;
- time series of a suitable price index otherwise.

In presence of trends in the time series, the trend component should be removed from time series variation prior to calculating the standard deviation of price or price index. Otherwise risks would be overestimated, especially in the case of substantial inflation.

Computer simulations setting

The empirical part of our study benefits from the data from three agro-industrial investment projects submitted to Krasnodar regional department of food and agriculture:

1) Slavyansky, aimed at rice processing;
2) Fishery, aimed at growing and processing fish;
3) The village of Voroshilov, aimed at milk processing.

We presume gamma distribution of managerial costs, labor costs and taxes. Assuming this distribution law for the remaining two components of cash flows causes computational problems, as it often happens with gamma distributions having low asymmetry. The reason is large magnitude of β in probability density of gamma distribution $p(x)=\frac{\beta^a}{\Gamma(a)}x^{a-1}e^{-\beta x}, x\geq 0$. Large β suggests minor difference between gamma and normal distribution. On this reason, we hypothesize normal distribution for revenues and material costs. In both cases the emerging probability of negative values of cash flow components appears ignorable.

The variance of cash flow components in each time period is calculated using one of the following formulae:

$$D_{x_{pfk}}=\bar{D}_{pf}\cdot x_{pfk}^2,\quad f=1,\ p\in\{2;3\},\text{ or}$$
$$D_{x_{pfk}}=\breve{D}_{pf}\cdot y_{pfk}^2,\ (f=\overline{2;5},\ p\in P)\vee(f=1, p=1), \qquad (2)$$

where x_{pfk} is value (in thousand rubles) of cash flow component f in period k caused by project p; y_{pfk} is projected sales (in thousand tons) of the commodity forming the corresponding f-component of cash flow of project p in time period k; $D_{x_{pfk}}$ is a variance of x_{pfk}; $\bar{D}_{pf}$ is a trend-free variance of the price index that corresponds to f-component of cash flow of project p; $\breve{D}_{pf}$ is a trend-free variance of price of the commodity forming the corresponding f-component of cash flow of project p. Indices: $f\in F$, $p\in P$, $k\in K_p$, where, just as in the previous section, K_p is a set of time periods covering the lifetime of project p; F is a set of cash flow components and P is a set of projects.

Table 1 provides point estimates of the variance of prices of project outputs. These estimates are used in calculations of the variance of inflows forming cash flow component $f=1$ of projects $p=2$ and $p=3$ (whereas the prices of rice are not available). Price indices engaged in modeling the remaining cash flow components are shown in Table 2.

Table 1

Consumer prices of outputs of the analyzed projects, rubles per kg

Output	Years					Trend-free variance $\breve{D}_{pf}$
	2004	2005	2006	2007	2008	
Live and refrigerated fish	58,48	68,27	73,94	82,93	99,67	244,27
Pasteurized milk	25,00	–	16,91	22,32	23,77	12,71

Source: [5], calculations by A. Arkhipova.

Table 2

Price indices used in the simulation of cash flows

Values	Years					Variance	Trend-free variance $\bar{D}_{pf}$
	2002	2003	...	2008	2009		
Polished rice consumer price index (p=1, f=1)	0,9997	1,012	...	1,01	0,99	0,000124	0,000121
Real wages index ($p=\overline{1;3}$, $f\in\{4;5\}$)	1,1765	1,1254	...	0,93	1,14	0,011448	0,010105
Industrial commodities producer price index ($p=\overline{1;3}$, $f\in\{2;3\}$)	1,394	1,546	...	2,85	2,75	0,366276	0,010772

Source: [5], calculations by A. Arkhipova.

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The following calculations illustrate how the data of Table 2 are used in determining variance of each cash flow component in each time period, using Slavyansky project ($p = 1$) as the case.

a) The revenue x_{112} for time period 2 (second quarter of the first project year), as shown in the business plan, is 18,26 million roubles. Its variance is $\bar{D}_{11} \cdot x_{112}^2$, where $\bar{D}_{11}$ is variance of polished rise consumer price index. Hence, we have $18{,}26 \cdot 0{,}000121 = 0{,}041$. Variance of revenue for other time periods is calculated in the same way, using the corresponding value of revenue.

b) The variance of material costs for time period 2 is calculated using the industrial commodities producer price index variance as follows:

$$\bar{D}_{12} \cdot x_{122}^2 = 20{,}028^2 \cdot 0{,}010772 = 4{,}053.$$

c) The variance of managerial costs for time period 2 is calculated in the similar way:

$$\bar{D}_{13} \cdot x_{132}^2 = 2{,}069 \cdot 0{,}010772 = 0{,}026.$$

d) The variance of labor costs for time period 2 is calculated using real wages index variance:

$$\bar{D}_{14} \cdot x_{142}^2 = 903^2 \cdot 0{,}010105 = 8783{,}3.$$

e) Calculation of the variance of tax payments for time period 2 also uses the real wages index variance. We found this index the most relevant among available ones, because the consolidated social tax, which depends on wages, commonly makes a substantial part of overall taxes in agro-industrial complex, whilst we have no evidence that amounts of other taxes correlate with some other official price index stronger than with real wages index. Insofar we have

$$\bar{D}_{15} \cdot x_{152}^2 = 384{,}9^2 \cdot 0{,}010105 = 1595{,}9.$$

Notations used in formulae above follow formula (2) in the beginning of this section. The results of the similar calculations are presented in Table 3.

Table 3

Variance $D_{x_{pfk}}$ of cash flow components in selected time periods (the case of Slavyansky project, $p = 1$)

Value	f	Quarters of project lifetime							
		1	2	...	9	10	...	13	14
Polished rice sales ($f = 1$)									
Inflow, million rubles	1	0	18,26	...	28,0	28,0	...	30,0	30,0
Variance of inflow, squared million roubles	1	0	0,041	...	0,095	0,095	...	0,109	0,109
Material costs ($f = 2$)									
Outflow, million roubles	2	0	20,028	...	19,8	20,13	...	19,8	20,1
Variance of inflow, squared million roubles	2	0	4,053	...	3,9	4,1	...	3,9	4,1
Managerial costs ($f = 3$)									
Outflow, million roubles	3	1,613	2,069	...	2,297	2,297	...	2,297	2,297
Variance of inflow, squared million roubles	3	0,026	0,026	...	0,026	0,026	...	0,026	0,026
Labor costs ($f = 4$)									
Outflow, thousand roubles	4	243	903	...	993,3	993,3	...	1072,8	1072,8
Variance of inflow, squared thousand roubles	4	636,1	8783,3	...	10627,8	10627,8	...	12396,3	12396,3
Taxes ($f = 5$)									
Outflow, thousand roubles	5	87,7	384,9	...	917,4	917,4	...	1018,9	1018,9
Variance of inflow, squared thousand roubles	5	82,9	1595,9	...	9066,4	9066,4	...	11183,0	11183,0

Source: calculations by A. Arkhipova.

Having computed the variance values, a random number generator is engaged to form ten thousand random quarterly time series of each cash flow component for each project (150 thousand series in total). Each uniformly distributed random number υ_{spfk} (where $s = \overline{1;10^4}$) produced by the generator is a percentile for corresponding gamma or normal distribution with the expectation value either x_{pfk} or y_{pfk}, depending on the nature of the specific cash flow component, and with the standard deviation equal to a square root of the corresponding value from Table 3. The monetary values in each time series are deflated to quarter 1 (inflation has been set aside) but not discounted regarding to opportunity cost of capital.

It is provided in the simulations that $\upsilon_{sp2k} = \upsilon_{sp3k} = \upsilon_{sp4k} = \upsilon_{sp5k}$. The meaning of this condition is that the four cash flow components of five are exposed to the same risks and vary simultaneously. This condition is an important difference of the proposed modeling framework from [1]. It enables a researcher to measure (subject to the model assumptions) the correlation between IRR of different projects.

Finally, variational series of ten thousand stochastic NPV and IRR values are computed for each of the three projects. These series are stored in the output database for the consequent statistical processing. Thus, an analyst or a potential investor are provided with the data that draw comprehensive picture of investment risk caused by price uncertainty. These data are sufficient for computing different point or interval estimates of any distribution moments.

Simulations of project cash flows in presence of governmental financial support

Within the framework of cash flow simulation we express risk in the probability of financial failure of a project, i.e. the probability of negative project NPV. Information on this probability is demanded by the project risk manager. Information demand due to the research aimed at political advice extends to the influence of governmental support on this probability. To satisfy this demand, we need to account for the probability of negative NPV in presence of such support with respect to its particular rule(s). In particular, if this probability is targeted, the simulation would be aimed in determining the amount of funds that, given the specific rule of support, provides exactly $\xi \cdot 10^4$ cases of negative NPV of ten thousand, where ξ is the targeted probability of negative NPV.

For the case of the three studied projects, the quantitative risk measures in absence of governmental support obtained from the performed simulations are presented in Table 4. The Fishery project is found to be the least risky, still demonstrating a very high risk. The Village of Voroshilov project demonstrates extreme risks, which are clearly unacceptable for investors. Notably, the original business plans give no idea about such severe risks. Apparently, the original risk analysis either has not been performed or has proved completely wrong.

Table 4

Estimates of project risks from computer simulations

Value	Project		
	Slavyansky	Fishery	The Village of Voroshylov
IRR in business plan, %	7,38	6,85	6,44
Average IRR throughout simulations, %	7,70	7,01	6,81
Standard deviation of IRR from simulations, %	4,18	2,13	4,80
Probability of negative NPV according to simulations, %	38,5	33,27	44,61

Source: calculations by A. Arkhipova.

The data of Table 5 reflects the influence of governmental financial support on the project risk. The modeled scheme of the support is that the government provides insurance payments for free, so that 100% of negative

NPV caused by price risk is re-paid from governmental funds, providing that the payment does not exceed a specified ceiling. Just for the simplicity we assume that the insurance payment arrives at the end of project lifetime, while any other scheme can be simulated as well. Prior to the further simulations, we compute the ceiling payment so to ensure the pre-defined probability of negative NPV after receiving insurance payment.

Table 5

IRR and its standard deviation under the specified levels of governmental financial support

Project	Probability of negative NPV in presence of insurance						No insurance
	0	0,1	0,2	0,3	0,4	0,5	
IRR							
Slavyansky	0,07681	0,07681	0,07680	0,07680	0,07680	0,07680	0,07677
Fishery	0,07443	0,07426	0,07406	0,07381	0,07355	0,07327	0,07010
The Village of Voroshilov	0,08143	0,08087	0,08012	0,07926	0,07826	0,07717	0,06811
Standard deviation of IRR							
Slavyansky	0,04176	0,04176	0,04176	0,04176	0,04176	0,04176	0,04177
Fishery	0,02127	0,02127	0,02127	0,02127	0,02128	0,02128	0,02130
The Village of Voroshilov	0,04636	0,04642	0,04651	0,04662	0,04674	0,04687	0,04804
Average insurance payment, million rubles							
Slavyansky	4,00	3,84	3,64	3,41	3,17	2,90	-
Fishery	10,61	10,20	9,68	9,07	8,44	7,73	-
The Village of Voroshilov	101,08	96,70	90,80	84,00	76,21	67,79	-
Average insurance payment, % to project investments							
Slavyansky	29,0	27,8	26,4	24,7	23,0	21,0	-
Fishery	0,7	0,7	0,6	0,6	0,6	0,5	-
The Village of Voroshilov	30,7	29,3	27,5	25,5	23,1	20,6	-

Source: calculations by A. Arkhipova and N. Svetlov.

For all the three projects, the state support simultaneously increases IRR and decreases (although hardly) its standard deviation. Slavyansky project, although not the least risky, is the least demanding in terms of state support in absolute figures. The Village of Voroshilov project demonstrates the largest growth of IRR and the largest decrease of its standard deviation. So, its attractiveness for investors improves greater than that of any other project. However, this outcome appears very costly for the government. In this regard, Fishery project seems to be the most responsive to governmental support, as the targets of negative NPV probabilities can be achieved at the costs that are less than 1% of private investments in the project.

Notably, large decrease in the risk of financial failure of the project is associated with a very small change in the standard deviation of IRR. This observation enables us to suggest that variance and standard deviation can be preferably used as ordinal risk measures, as their magnitude is scarcely informative.

Simulation of investor's behavior in presence of governmental financial support

In addition to the probability of negative NPV, the simulation of cash flow provides the input data for portfolio modeling using Markowitz scheme. This stage of simulation satisfies the *investor's* demand for information. Moreover, it is essential for the *researcher* whose aim is to inform the government about the investor's reaction on each scenario of supporting policy. Comparing portfolios formed under various levels and scenarios of state support enables the researcher to make judgments about capability of each policy to attract private capital into politically important projects (e.g. from the point of view of national food security).

Markowitz modeling scheme receives from the cash flow simulation both mean and standard deviation of each project's IRR and correlation coefficients of IRRs across the performed simulations. The IRR is comparable to the normalized income from a security, thus taking place of $\mu_{i''}$, where $i'' \in I''$, in problem (1). Its standard deviation takes place of σ_i, $i \in I''$, and linear correlation between IRRs of two projects substitutes r_{ij}, where $\{i; j\} \subseteq I''$. Table 6 below presents the latter values obtained from cash flow simulations. Slavyansky and Fishery are the least correlated, so their simultaneous presence in a portfolio reduces overall investment risk greater than the presence of any other pair.

In this study a project's IRR and a security's normalized income is assumed to be orthogonal, so $r_{ij} = 0$ when $i \in I''$ and $j \in I'$. However, it is possible to approach the values of r_{ij} by running special cash flow simulations, in which actual prices and price indices data are used to access IRR under the same conditions on which the normalized income of securities was observed. Such simulations are planned for the future.

Table 6

Linear correlation between IRR of agro-industrial projects obtained from cash flow simulations

	Slavyansky	Fishery	The Village of Voroshilov
Slavyansky	1	0,159	0,390
Fishery	0,159	1	0,332
The Village of Voroshilov	0,390	0,332	1

Source: calculations by A. Arkhipova.

After having solved the modified Markowitz model that simulates some scenario of supporting policy, the optimal portfolio and its attributes are saved in the output database so to enable their processing later on.

Despite their extreme risk, the projects used in our study take a small share in the investment portfolio formed, for the most part, of a set of securities of large companies (Table 7). In our case these companies are

agroholdings: Razgulyai Group, Sinergiya, Rusgrain Holding and food industry companies: Krasny Oktyabr', Cherkizovo, Baltika and Vimm-Bill-Dann. Availability of the state support of real projects substantially increases their share, although they never dominate in the portfolio.

The data of Table 7 enables us to conclude that the projected scenario of state support aimed at decreasing the probability of negative NPV to the targeted threshold (which is assumed to be equal for all the three projects) significantly influences the portfolio in favor of the supported agro-industrial projects. Their share in the portfolio increases from 19,8% up to 32,8%, making 13,0 point growth. The governmental support amounting (expectation value) to 2,343 million roubles per 50 million roubles investment portfolio attracts 6,510 million roubles of private capital in addition to 9,913 million roubles that would be invested in real projects in the absence of support.

Table 7

Simulated 50 million roubles investment portfolio having 12% annual income under the specified levels of governmental financial support

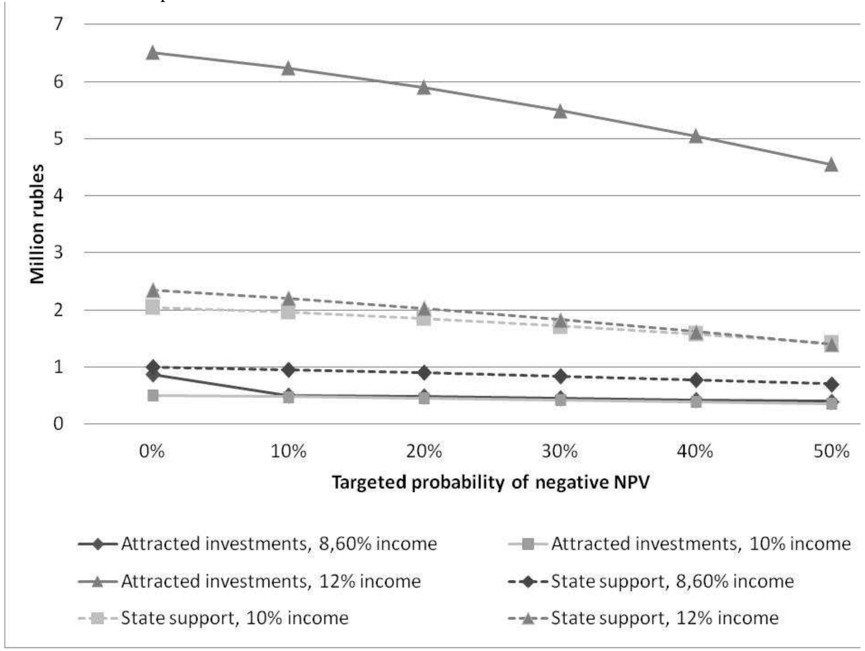
Targeted probability of negative NPV, %	Gross amount of governmental support, million rubles	Gross investments in the real projects, million rubles	Gross investments in securities, million rubles
0	2,343	16,423	33,577
10	2,204	16,152	33,848
20	2,022	15,813	34,187
30	1,826	15,402	34,598
40	1,616	14,958	35,042
50	1,402	14,469	35,531
No support	–	9,913	40,087

Source: calculations by A. Arkhipova.

Picture 2 demonstrates the amounts of attracted private investments and governmental financial support in connection to the targeted probability of negative NPV and expected income. As it can be seen in the chart, the proposed partial compensation of investor's risk at the expense of governmental funds, tested by the instrumentality of the developed simulation framework, makes it possible to achieve the competitive portfolio income at the acceptable level of risks. The trade-off between the amount of attracted private funds and governmental expenses is up to a decision maker, who takes into consideration both strategic priorities of governmental agro-industrial policy and the opportunity cost of governmental expenses.

Conclusions and discussion

The developed framework of cash flow and investment portfolio simulations proves its ability to provide valuable data for the purposes of project risk analysis and management, for making decisions about funding real sector projects under risky conditions (specifically, when price risk is the most important) and for foreseeing invesstors' reaction on the governmental policies aimed at attracting private capital in a specific sector, e.g. agro-industrial complex.



Source: calculations by A. Arkhipova.

Pic. 2. Gross state support and amount of additionally attracted private funds depending on the targeted probability of negative NPV of agro-industrial projects (the portfolio is worth 50 million rubles).

Moreover, the application of this framework to the case of three agro-industrial projects that pretend to be implemented in the Krasnodar kray has shown that the compensation of negative NPV at the end of a project's lifecycle can influence investors' behavior so that the attracted private funds exceed the governmental expenses up to 2,7 times, subject to the set of securities that are considered in this study as alternative portfolio investments. The larger the portfolio income the investor expects to receive the greater the effect of governmental support.

This result enables us to conclude that the governmental policies aimed at attracting private capital into agro-industrial projects via reducing investors' risks are capable to substantially improve the capital inflow in agro-industrial complex. On this reason we believe that the specific forms, scales and targets of governmental support call for extensive studies, which can largely benefit from the developed methodological framework.

In the framework of this study the applicability of one of the two above mentioned distribution probabilities to any cash flow component in each time period is hypothetic. Consequently, validity of our conclusions is subjected to the validity of this hypothesis, which, to be accepted, needs to be tested in each application. However, in practical applications, when such testing is not possible, the decision maker can take the risk of unacceptability of this hypothesis. To provide the data for performing regular tests, the existing data gathering infrastructure of extension service needs to be extended. The collected data would be useful for many other analytical, risk-management and research purposes. For the moment it is not clear, though, whether such extension will repay its cost.

The restrictive assumption of certainty of all in-kind amounts throughout the project biases down the standard deviation of each cash flow component. In this regard, we rely on the general methodological position of risk management, which suggests that the scope of objective risk management is such risks that are amenable to elucidation, estimation and analysis (e.g. [8]). Insofar, the sources of variance of cash flow components other than the prices fall into the category of risks that cannot be objectively analyzed given the existing level of methodology and information base. On the contrary, there may exist specific data sources about some or all cash flow components of some specific projects, which are not taken into consideration in our study. Using these sources to compute standard deviations does not require extensive modifications in the toolset we propose, providing a higher level of risk protection in comparison to the general situation.

Another open research question is approaching correlation between the normalized incomes of securities and real sector projects. Although it is clear in the theoretical sense how to measure this correlation, the empirical part of this study needs to be extended so to obtain more accurate conclusions about investors' behavior both in absence and presence of governmental financial support of agro-industrial projects.

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Применение исследования операций для привлечения инвестиций в аграрно-промышленный комплекс

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Обоснована возможность применения имитационного моделирования для удовлетворения информационной потребности, возникающей при анализе рисков инвестиционного портфеля, предусматривающего вложения во взаимосвязанные реальные проекты. Разработан комплекс имитационных моделей потоков денежных средств и инвестиционного портфеля, позволяющий определять статистические характеристики экономического эффекта инвестиционных проектов и оценивать вероятный объём инвестиций в реальные проекты в условиях их финансовой поддержки государством. Эмпирическая база имитационной модели образована проектно-сметной документацией, данными о вариации цен продукции, получаемой в результате проекта, а также индексами цен. Инструментальные методы, в основу которых положена разработанная модель, позволят принимать обоснованные решения о вложении капитала в инвестиционные проекты, о формах и размерах государственной поддержки, направляемой на повышение инвестиционной привлекательности АПК.

Ключевые слова: оценка риска проектов, портфельные инвестиции, поток денежных средств, поведение инвестора, модель Марковица, имитационное моделирование.

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