An innovative methodology for evaluation

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Abstract. The article describes the methodology of valuation, based on the use of agent-based modeling. To estimate the cost, it is proposed to obtain a variational series of calculated prices using the method of statistical tests on the basis of the game-theoretic model of interaction between the seller and the buyer with random parameters (price-forming factors). The article presents a specific version of such a model and an example of its application. The model allows, instead of selecting one of the estimates of the price-forming factor, to use the entire set of applicable estimates. The model provides automatic matching of evaluation approaches. As a result, valuation is more free from subjective distortions. The presented methodology is fully consistent with Russian and international evaluation standards. In contrast to the known analogues, the presented methodology allows to minimize the subjectivity of the assessment, in all cases to obtain a verifiable result, objectively assess the interval of the possible results of appraising.

Keywords. Value appraising, Agent-based modeling, Game theory, Monte Carlo methods.

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1 Introduction

Modern practice requires a clear and sustained final results of cost estimation. Historically, modern valuation methodology with its three approaches (cost, comparative and revenue), harmonization of the results of their application, the definition of the concept of market value and the principle of the most effective use, eventually arose under the influence of us judicial practice in the middle of the XX century.

Paradoxically, the historical valuation methodology does not reflect the notion of value. Indeed, according to the international valuation standards, the value is the most probable price to be paid for an asset in an exchange, that is, a statistical description of the variation series of calculated prices. It is obvious that, literally following the norms of the legislation on valuation activities, to establish the value, it is necessary first to determine by calculation a number of prices in hypothetical transactions, and then to find its stable statistical characteristic.

However, valuation theory prescribes the determination of value using three approaches to valuation and the subsequent harmonization of results by weighing on the basis of subjectively defined weights. For each of the approaches, the cost is determined separately by applying one or more evaluation methods freely chosen by the appraiser within the framework of this approach using the source data, which are also selected by the appraiser independently. This is a deterministic calculation of the cost without taking into account the variation of possible parameters. But from this algorithm it does not follow that the result of such estimations is the value as the most probable price.

The evaluation methodology used now is artificial and far from the real process of pricing. It contains the risks of errors and conscious manipulation of the evaluation result. The result of the valuation loses its reproducibility from one appraiser to another. Accordingly, the prestige of the profession of appraiser is undermined, at least in Russia the appraiser is often considered not as a professional, but only as a trader of fabricated assessment reports, which contains a predetermined value of the object of evaluation.

To correct the situation, there is a need to revise the evaluation methodology, or rather, the development of a new, more rigorous, evaluation theory, which would reflect the objective variability of pricing parameters, possible methods and models of evaluation.

In the present article an approach to the construction of such a theory based on agent modeling with the use of game theory is proposed. It should be noted that the idea to apply the theory of games to determine the individual equilibrium in the valuation is not new. It can be considered that in Russia it was expressed 10 years ago [3]. However, since then, neither the Russian nor the world valuation methodology has undergone any changes. One possible reason is that the idea in [3] and also in [1], [2] has not been worked out in terms of both the individual equilibrium and the transition from the individual equilibrium to the market value. There is an article 10 years ago [4], which also points to the applicability of the theory of games to describe the pricing mechanism. Unfortunately, it considers a rather abstract case of matrix game and does not contain any algorithm that could be used to solve the problems of valuation.

2 Agent-based model of evaluation

The meaning of the proposed approach is to simulate a hypothetical market by going through all the interactions of sellers and buyers, determining the esti-

mated values of the price and finding the mathematical expectation of prices in accordance with the definition of the concept of value. In General, such a simulation is feasible with the use of computational methods. We propose the following algorithm for establishing the value, which, in our opinion, sufficiently corresponds to the rational market behavior.

Market interaction is seen as a game of $M + N$ persons: M sellers and N buyers. The goal of the seller j is to sell the available quantity of the item Q_{sj} as expensive as possible, and buyer i to purchase the necessary quantity of the goods Q_{di} as cheaply as possible. Prices of deals and prices are not known in advance and are determined only by the results of the game.

Each player has restrictions ("buy not more expensive than ...", "sell not cheaper than ..."), reflecting his economic interests. Limitations (economic interests) are described by an evaluation approach. To date, there are three approaches to the assessment: cost approach (the price should pay the cost), income approach (the price should correspond to the expected future income) and market approach (the price should correspond to possible substitutes).

Different types of sellers and buyers are possible in the same market depending on their economic interests. Accordingly, different approaches and models within each approach apply to them.

In order to more accurately take into account economic interests in the future, both the emergence of new approaches and the transformation of existing ones are possible. For example, for consumer goods, as well as in the case of an investment value assessment, it is generally necessary to assess the usefulness of the object of assessment rather than future income.

In the first step of the game, each j-th seller by applying all relevant approaches for him (that is, based on their different economic interests), makes different estimates of the possible price of the transaction: $P_{sj}^{(1)}, P_{sj}^{(2)}, \ldots$, and determines for himself the marginal price of the proposal, below which he is not ready to sell the goods, unless the transaction is mandatory for him: $P_{sj}^{\min} = \min\limits_{k} P_{sj}^{(k)}$, $k = 1, 2, \ldots$.

Because the seller is rational, then each of the values $P_{sj}^{(k)}$, he or she determines by calculation on the basis of available baseline data $\overrightarrow{x_{sj}}$: $P_{sj}^{(k)} = f_k\left(\overrightarrow{x_{sj}}\right)$.

This particular seller has one random set of initial data of the total number of options that may be available: $\overrightarrow{x_{sj}} \in \Omega_s$. If at some l-th component $x_{sj}^{(l)}$ of the vector $\overrightarrow{x_{sj}}$ the seller is available for a variety of estimates $X_l = \left\{\dot{x}_p^{(l)}\right\}$, then he or she selects a specific value in a random way. To do this, each evaluation $\dot{x}_p^{(l)}$ is considered representative of the corresponding interval continuous random variables $X_{sj}^{(l)}$: $X_l = X_{sj}^{(l)}$. Because of the Bayes' postulate entering values in any of the intervals are considered equally probable. Thus, the probability distribution of the random variable $X_{sj}^{(l)}$ is given, and its concrete value is found using the Monte Carlo method.

Buyer i similarly determines the maximum allowable price of demand $P_{di}^{\max} = \max\limits_{k} P_{di}^{(k)}$, above which, in the presence of freedom, he or she will not make a deal.

To do this, each buyer has one random set of initial data of the total number of options that may be available: $\overrightarrow{x_{di}} \in \Omega_d$. In the case of information asymmetry there is: $\Omega_s \neq \Omega_d$.

In the second step of the game of the total set of players for which not all the amount of the proposed (requested) product is exhausted by a special algorithm at random, taking into account the ratio of sellers and buyers chosen lead player the one who begins an active search counterparties and chooses the best price for himself. In the model, the number of counterparties that are moved by the leading player can be limited.

If the leading player is the j-th seller, than the best option for him or her is the buyer i, which agree on the maximum price demand in non-zero quantity of the good: $P_{di}^{\max} = \max\limits_{k} P_{dk}^{\max}$, $Q_{dk} > 0$, $k = 1, \ldots, N$. If the leading player is the i-th customer, than the best option for him or her is the is seller j, which agree on the lowest offer price in a non-zero quantity of the good: $P_{sj}^{\min} = \min\limits_{k} P_{sk}^{\min}$, $Q_{sk} > 0$, $k = 1, \ldots, M$.

If $P_{di}^{\max} \geq P_{sj}^{\min}$, or if the transaction is required for a leading player, needs to be fixed the new deal with the number w at the price of

$$P_w = P_{ij} = \frac{1}{2}\left(P_{sj}^{\min} + P_{di}^{\max}\right)$$

and the quantity $Q_w = \min\{Q_{di}; Q_{sj}\}$. Otherwise, the new deal is not fixed.

The remaining amount of goods in players is reduced by the value of Q_w. The process is repeated until the number of evaluation objects with which the transaction can be made has been exhausted.

The value estimated as the weighted average price of fixed deals:

$$P_c = \frac{\Sigma_w P_w \cdot Q_w}{\Sigma_w Q_w}$$

Due to the use of random selection, each valuation based on the results of one game is a random variable. So game are doing the correct number of times to achieve stable estimates of the average absolute deviation. The median of the obtained variation series $P = Me\{P_c\}$ is taken as the final value as the smallest expected absolute error [5]. The additional result is a reference indication of the lower and upper limits of the value range, which in principle is possible under the specified conditions.

3 Implementation

As an example, we give a traditional assessment of the market value of the property, which includes a land plot with a warehouse building located on it. It is known that as of the valuation date, 16 sellers sell similar objects, the number of potential buyers according to different estimates is 1, 5 or 7. Other initial data are given in table 1 (all monetary figures are in euro).

Table 1. Baseline data for the valuation of market value.

Side of the transaction	Applicable approach	Pricing model	Values of parameters
Seller	Cost Approach	$C \cdot (1+i) \cdot (1-f)$	The cost to obtain an asset of equal utility (C): 25350; 27480; 28550. The rate of profit (i): 0.04; 0.07; 0.10; 0.12. The rate of obsolescence (f): 0.04; 0.068.
Buyer	Market Approach	P_a	The adjusted price of identical or similar assets for which price information is available (P_a): 20350; 22410; 27600; 28690; 33005; 35800.
Buyer	Income Approach	E/r	The annual net income (E): 5100; 5300; 6540; 6720. The rate of capitalization (r): 0.16; 0.21; 0.24; 0.25; 0.255.

Table 2. Results of evaluation on the proposed model.

The number of attempts	The upper bound of the obtained values of the valuation (reference)	The estimated value (median of the obtained values)	The upper bound of the obtained values of the valuation (reference)
1	24773	29297	35066
2	24112	29079	32411
3	25270	29345	34184
4	25603	29399	36877
5	25226	29114	33080
6	25493	29453	34042
7	24830	29001	33074
8	24874	28688	32060
9	24839	29106	35746
10	25103	29548	33035
An average of all attempts	*25012*	*29203*	*33957*
Standard deviation	*406*	*242*	*1463*
Coefficient of variation	*1.6%*	*0.8%*	*4.3%*

To assess the sustainability of the results of the proposed model, 10 attempts for determining the total cost were implemented. In each variant the game was played 100 times. The results are shown in table 2.

It is easy to see that the results obtained have a high degree of stability and exceed the point results traditionally obtained by the evaluator. An example of a result, based on the subjective choice of a particular value and the weights of the matching, is given in Table 3.

Table 3. Parameters of the probit regression model.

Applicable approach	Pricing model	Values of parameters	Weight	The estimated value
Cost Approach	$C \cdot (1 + i) \cdot (1 - f)$	$C = 27480$; $i = 0.1$; $f = 0.068$.	0.333	28172
Market Approach	P_a	$P_a = (20350 + 22410 + 27600 + 28690 + 33005 + 35800)/6 = 27143$.	0.333	27143
Income Approach	E/r	$E = 5100$; $r = 0.24$.	0.333	21250
The weighted estimated value				25522

The comparison of table 2 and table 3 shows that the point result, traditionally obtained by the appraiser, does not use all available information, resulting in a narrow and unstable picture of value. Moreover, in this case using the traditional approach have led to an underestimation of the cost compared to the rating that gives the least expected absolute error (use another dataset for point estimates may lead to overestimation).

3.1 Summary

Thus, the proposed methodology allows to:

1. Determine market or any other value of object of an assessment in exact accordance with its definition, by means of simulation of behavior of participants of hypothetical transactions.
2. Use the entire set of valuation models available to the appraiser, which can be applied by the seller and the buyer, and for each model, the entire set of parameter value estimates available, even if these estimates differ significantly.
3. Use of all relevant approaches and methods of evaluation is differentiated between the seller and the buyer, and the results of these approaches and methods will be agreed automatically.

The advantage of the proposed methodology is that it allows the evaluator not to be afraid and not to avoid plurality and inconsistency of data and different

ways of their use, and to take into account all of them to obtain the most sustainable and reasonable result.

The proposed methodology makes the function of the evaluator more specific. The evaluator becomes a professional statistician, whose task is to collect and process qualified information. Research intensity and significance of his work at the same time significantly increases.

It seems that the methodology described above makes it possible to overcome the existing evaluation crisis and intensify the development of new valuation models, as well as to ensure the convergence and mutual enrichment of the theory of valuation activities and economic theory. We can say that the theory of evaluation makes a scientific order to the microeconomics to develop models of various economic interests, monetary utility assessment, etc., and in return gives its experimental base, enriches empirical information. Perhaps in the future the theory of evaluation will become a natural part of microeconomics.

Meanwhile, the methodology can be successfully applied now, without waiting for the development of more advanced models of price behavior of the seller and the buyer.

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