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MODERN TOOLS FOR MODELING FINANCIAL MARKET IN MATHEMATICA ENVIRONMENT

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СУЧАСНИЙ ІНСТРУМЕНТАРІЙ МОДЕЛЮВАННЯ ФІНАНСОВОГО РИНКУ У СЕРЕДОВИЩІ MATHEMATICA

The financial market is a complex system influenced by a significant number of signs-factors, and its functioning is determined by a significant number of signs-results. The complexity of the model leads to the fact that when building financial market models, it is necessary to use different types of systems of the one-dimensional equations, which the model can contain from 2 to n equations, so it is difficult to form and study them not far too modern means and tools of symbolic mathematics. It is important to note that the means and instruments of symbolic mathematics, which are summarized in the Mathematica program, may quickly draw up a model of the financial market. Therefore, the study is a general description of financial market modeling tools using systems of the same equations in MATHEMATICA. The study uses methods of analysis, synthesis, and logical analysis. As part of the study, note that a model consisting of unidentified or difficult-identified equations cannot be the subject of the study, because it is considered to be of poor quality. According to the results of the study, it is proved that the MATHEMATICA program implements the mathematical expressions works included in the financial market model until it forms more identical or identical sets of equations. The program MATHEMATICA implements the study of the financial market model using the indirect method of the smallest squares and the following algorithm of actions: — form the primary form of the financial market model to identify the form of its equations; start the process of model equalization analysis by the method of the smallest squares; systematization of equality assessments for the structural form of the financial market model. Evaluation of over-identified equations by the method of the smallest squares can be stopped at the second step, as it is evidence of the quality of all the stipulated variables. The prospects of further research lie in the development of methods of modeling the financial market using uniform systems of equations and means of symbolic mathematics.

Фінансовий ринок є складною системою, на яку впливає значна кількість ознак-факторів. Крім того функціонування такої системи визначає значна кількість ознак-результатів. Окреслена складність призводить до того, що при побудові моделі фінансового ринку треба вдаватися до використання різних (за видами) систем одномірних рівнянь. Така модель може містити від 2-х до n рівнянь. Відтак, їх досить складно сформувати й дослідити не вдаючись до сучасних засобів та інструментів символьної математики. Важливо зазначити, що за засобами та інструментами символьної математики, які узагальнені в програмі MATHEMATICA, можливо швидко сформувати модель фінансового ринку. Стрижнем дослідження є загальний опис інструментарію моделювання фінансового ринку за допомогою систем одномірних рівнянь у програмі MATHEMATICA. У межах дослідження звернено увагу на те, що модель, яка складається з неідентифікованих або складно ідентифікованих рівнянь, не може бути об'єктом дослідження, оскільки вона визначається як неякісна. За результатами дослідження доведено, що за своїми інструментами програма MATHEMATICA реалізує роботу з виразами, що включені до моделі фінансового рику то тих пір, поки не сформує понад ідентифіковані або ідентифіковані набори рівнянь. Програма реалізує дослідження моделі фінансового ринку за допомогою непрямого методу найменших квадратів, використовуючи наступний алгоритм дій: формування первинної форми моделі для ідентифікації її рівнянь; запуск процесів аналізу рівнянь моделі за методом найменших квадратів; систематизація оцінок рівнянь для структурної форми моделі. Оцінка понад ідентифікованого рівняння за методом найменших квадратів може бути зупинена на другому кроці, оскільки вона є свідченням якості всіх зумовлених змінних. Перспективи подальших досліджень полягають в розробці методики моделювання фінансового ринку за допомогою одномірних систем рівнянь та засобів символьної математики.

Key words: model; one-dimensional equations; systems of equations; sign-result; sign-factor.
Ключові слова: модель; одномірні рівняння; системи рівнянь; ознака-результату; ознака-фактору.

PROBLEM-SETTING AND ITS RELATION TO IMPORTANT SCIENTIFIC OR PRACTICAL OBJECTIVES

The financial market is a complex system, which is influenced by a significant number of signs-factors and the functioning of which is determined by a significant number of signs-results. The complexity of the problem leads to the fact that in building a financial market model not always possible to implement it help of multi-agent modeling (namely, the creation of a scheme of actions or interaction of autonomous agents) or one ratio, which is offered within the models formed by the equalization of a pair linear regression or non-linear regression (according the initial data on the functioning of the financial market are the single values X (i.e. signs— factors) and Y values (signs— results), multiple regression equations (according to which the initial data on the functioning of the financial market are multiple values X (that is, signs of a significant number of factors) and values Y (signs— results)). This is due to the following problem of the models described: 1) some variables XY gives mutual influence, so it is impossible to determine which of them is dependent X, and which independent variable Y; 2) signs of a significant number of factors can be multicollinearity, which leads to uncertainty of parameters in the model regardless of the chosen methods of testing for it. The desire to solve the restated problem leads to the fact that when building the model of the financial market it is necessary to resort to systems of equality.

ANALYSIS OF RECENT STUDIES AND PUBLICATIONS

Among the main researches in which the solution to the problem of modeling the financial market can be identified are Plastun O., Makarenko I. [5], Mykhalchynets, H. [4], Strichenko K., Dmitriusenko K. [6], Kazakova, N.F. [3]. However, most of the above scientists focus only on multi-agent modeling, or on equation of pair or multiple linear regression. The tools of such modeling and research of such models are unstudied for single-dimensional equations systems. In particular, there is no specificity concerning the use of all the involved variables, their typology, methods of construction, and operation of equations systems. Thus, the process of the research relied mainly on fundamental developments in the field of systems of the same level (among them works V. Chibiriakov, A. Stankevich, D. Levkivsky, V. Melnychuk [2] and Kazakov N. [3]).

FORMULATION OF THE OBJECTIVES

The purpose of the article is to describe the tools of financial market modeling using systems of the same level in MATHEMATICA.

PROBLEM-SETTING AND ITS RELATION TO IMPORTANT SCIENTIFIC OR PRACTICAL OBJECTIVES

Although the content of the signs-factors and the signs-result that holds the financial market model is formed depending on the final application goals, its construction is classic and is built on the sum of the instruments that are the same for all the same levels of regression (among which the linear differential equation and its variations). In particular, the model is selected:

1. Abstract variables, whose values are set outside the financial market system but influence it (e.g., GDP, export and import volumes, inflation rates, etc.). Such variables are identified as signs-factors (X);

2. Abstract variable values formed within the system of the financial market or mutually dependent (for example, the exchange rate of the national currency, foreign currencies, the equal income of credit and deposit operations, annual income of securities, etc.). Such variables are identified as indicators of signs-results (B);

3. LAG signs-result, in a single numerical expression adopted for the financial market model. These are all У dated by the preliminary moments, provided that they are at the same level. Among such LAG variables are distinguished by: yt — current sign-result, yt-1 — LAG sign-result (which is far from the current one for 1 period), yt-2...n — a LAG sign-result (which is far from the current one from 2 to n periods). Accordingly, the financial market models contain the right part of the LAG-standing changes, which take into account the Y trend of changes;

4. Variable or sign-factors, whose value is formed outside the financial market model. They include the LAG

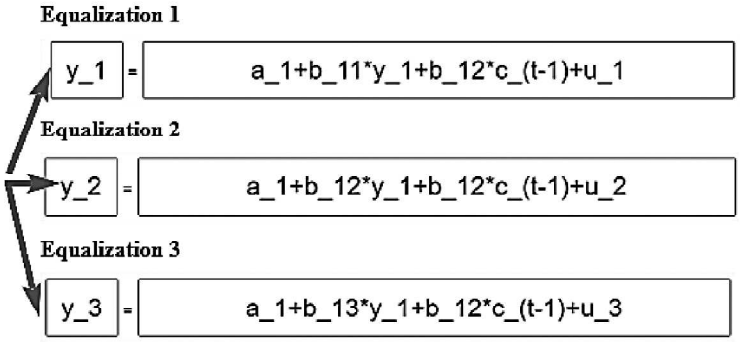

Figure 1. The standard look of the function of expression working in the program MATHEMATICA

Source: Mathematica program environment.

and current variable sign-factors (xt, xt-1) and LAG variable sign-results (yt+1) [2; 3].

The combination of the above-mentioned variables in the system of one-dimensional equations forms a model of the financial market with the possibilities for explaining the current values of the sign-result using the values of the sign-factors selected. Note that since such a model can contain from 2 to n equations, its formation, and research it is expedient to implement it with the help of programs in symbolic mathematics, one of which is MATHEMATICA. The outlined program allows to form a model of the financial market:

— containing up to 10 single-dimensional equations (eliminating the complexities associated with errors in the specification of such a model);

— based on different types of systems of the one-dimensional equation, among them: system of independent equations (or system of type 1); system of recursive equations (or system of type 2); system of mutually dependent equations (or system of common, simultaneous type).

We will consider a detailed set of tools that can be available within MATHEMATICA for financial market modeling.

The tool for determining the number of single-dimensional equations (the function of working with the visas) requires correct work with the mathematical expression that reflects their contents. For example, if the content of the single-dimensional equation makes up the expression y1=c1+b12y2, then in MATHEMATICA it should be converted by algorithm y_1=c_1+b_12*y_2. In case the index summarizes the LAG values Yt-1, it should be converted by algorithm Y_(t-1). The standard look of the image function is shown in Figure 1.

It is important to note that the function of expression working does not provide for a variable random error εt (or ut) (it automatically selects it). At the same time, within the framework of entering expressions the outlined function should set up a general model of the financial market carried out by connection of the following options: (Table 1): 1) use of a single standard of registration; 2) use of necessary (sufficient) conditions of identification of the contents of the model; 3) use of necessary and sufficient conditions for identification of the structural form of the model; 4) formation present form of the financial market model.

Table 1. Options for setting up the function of expression working included in the financial market model

Option	Specific operation of the function of expression working	Special features of the setting up the function
use of a single standard of registration	this process is based on the additional marks entered into the model, including: (M) the number of symptoms; (m) the number of defined variables in each equation; (K) the number of symptoms; (k) the number of variables K in the equation	by marks to variable of equation
use of necessary (sufficient) conditions of identification of the contents of the model;	if the financial market model is identical, if all included equations are clearly defined (however, if there is at least one unidentified among the equations - the whole financial market model is not identical)	by the coefficients of the given model*
use of necessary and sufficient conditions for identification of the structural form of the model;	the financial market model receives such identification only in its structural form	according to the terms of model equalization identification**
formation present form of financial market model	this process involves checking each equation of the structural model of the financial market for identification with an assessment of the parameters of the structural form of such a model.	

Note

* The number of model variables and coefficients of the model identified should be the same.

** sufficient condition of the equality identification in the model oriented on the rank of matrix A (it formed by additional values for the matrix of coefficients at variables not included in this equation).

Source: Mathematica program environment, [3; 7].

In the MATHEMATICA program, the following algorithm for identification of the financial market model uses:

1) the equation is identical if the estimates of all structural parameters can be determined by the coefficients of the given model;

2) the equation is more identical if up to 20% of the structural parameters can be obtained from more than one numerical value (thus forming only the coefficients of the given model);

3) equations are unidentified if estimates of its structural parameters cannot be determined (and the coefficients of the above model are partially absent).

MATHEMATICA program uses a specific algorithm for the necessary and sufficient identification of the structure of the financial market model.

For example, the conditions that are necessary but insufficient for the identification of structural equalization in the model are not automatically set. For the equalizations to be identified as part of the model, the number of pre-defined variables outside the equalizations mustn't be less than the "number of signs-result variable" included in the equation with the minus of the unit. MATHEMATICA program algorithms check for unequal fulfillment of M-m>=k-1, however, it does not produce the result if there is no data to interpret the results. Therefore, the basic interpretation of the results is proposed to make the following scale of values: If M-m=k-1 the equation in the structural form is exactly identified; if M-m>k-1, the equation in the structural form is over-identified.

Conditions sufficient to identify equations in structural form in the model in MATHEMATICA program are triggered only if additional labels are entered for the coefficient of variables not included in the equation (A). At that, the software algorithms already provide that sufficient condition of identification of equations in the model is oriented on the rank of a matrix A (what is the size of its largest square submatrix, the definition of which 0), which should be equal K-1. In fact, MATHEMATICA software algorithms check does the value matrix rank equal K-1, but does not produce the result of such validation unless the basis for interpreting the results is provided. Therefore, we propose to make the system of the following equality the basis of interpretation of results: if M-m>k-1 and matrix rank A = K-1, then equation over identified; if M-m=k-1 and A=K-1, then equation exactly identified; if M-m>=k-1, and A less than K-1, then equation hard to identified; of M-m<k-1 (then A less K-1), then equation not identified.

It is important to note that the financial market model, consisting of unidentified or difficult-identified equations, cannot be the subject of research. In other cases, the MATHEMATICA program can build a financial market model through various equalization systems, which are formed depending on the type o equations introduced by the function of the expression of the equation. To do this, the MATHEMATICA program operates the download sets of algorithms presented below [7]:

1. the operation of independent equations algorithms started when all entered expressions of equations have a variable (y) and are considered as a function of conditional variables (x). Under these conditions, the financial market model will take the form 1:

$$\begin{cases} y1 = a11x1 + a12x2 + \cdots + a1mxm + u1 \\ \cdots \\ y1k = ak1x1 + ak2x2 + \cdots + ak2xm + uk \end{cases} \quad (1);$$

2. operation by recursive equations algorithms, which are started if every next expression has a dependent variable, and it forms a function depending on the variable (on the previous equations). Under these conditions, the financial market model will take the form 2:

$$\begin{cases} y1 = a11x1 + a12 + a1mxm + u1 \\ y2 = b21y1 + a21x1 + a22x2 + \cdots + a2mxm + u2 \\ y3 = b31y1 + b32y2 + a31x1 + a32x2 + \cdots + a3mxm + u3 \\ \cdots \\ \cdots \\ yk = bk1y1 + bk2y2 + \cdots + b_{kk-1}y_{k-1} + ak1x1 + ak2x2 + \cdots + akmxm + uk \end{cases} \quad (2);$$

3. the operation of algorithms mutually dependent equality (or a common, simultaneous types), which are started provided that dependent variable in the same equations included in the left-hand side (it is signs-result), and in others to the right-hand side (it is a signs-factors). Under these conditions, the financial market model will take the form 3:

$$\begin{cases} y1 = b12y2 + b13y3 + \cdots + b1kyk + a11x1 + a12x2 + \cdots + a1mxm + u1 \\ y2 = b21y1 + b22y2 + \cdots + b2kyk + u21x1 + u22x2 + \cdots + u2mxm + u2 \\ \cdots \\ yk = bk1y1 + bk2y2 + \cdots + b_{kk-1}y_{k-1} + ak1x1 + ak2x2 + \cdots + akmxm + uk \end{cases} \quad (3);$$

In this case, in the Mathematica program, if the financial market model is formed by multi-level systems of equations, the system of each level is considered independently. The equations in this programming environment are determined using the least squares method.

The general research of the financial market model can be carried out by the indirect method of the smallest squares (hereinafter referred to as "KMNK"). For this purpose, we offer to launch in the MATHEMATICA program the following algorithm of actions:

Step 1 — Form the primary form of the financial market model to identify the form of its equations.

Step 2 — Start the process of model equalization analysis by the method of the smallest squares (the results of the analysis are given to each model equation separately with mandatory numerical estimates of their content).

Step 3 — systematization of equality assessments for the structural form of the financial market model, using the ratio found in step 1.

The evaluation of over-identified equalization by the least square's method can be stopped at the second step, as it is an indication of the quality of all the variables [7]. The algorithm of actions is as follows:

Step 1 — Form the primary form of the financial market model to identify the form of its equations.

Step 2 — Start the process of analysis of model equations by the method of the smallest squares. The analysis results are presented to each model equation separately with obligatory numerical assessments of their content. At the same time, it is necessary to define: a) the calculated values of the sign-result, which appear in the structural form of the model; b) the structural parameters of each equation separately (using the factors included in the equation and the calculated values of the sign-result, obtained in step 1).

CONCLUSIONS AND PROSPECTS FOR FURTHER RESEARCH

It is important to note that the means and instruments of symbolic mathematics summarized in Mathematica program, may quickly select the financial market model. This is because a model that consists of unidentified or difficult-identified equations cannot be the subject of the study. After all, it is identified as low-quality. Accordingly:

1. According to its tools, the MATHEMATICA program is working with the expressions, included in the financial market model, until the formation of over-identified or identified sets of equations.

2. The program implements the study of the financial market model using the indirect method of the smallest squares and the following algorithm of actions: — form the primary form of the financial market model to identify the form of its equations; start the process of model equalization analysis by the method of the smallest squares; systematization of equality assessments for the structural form of the financial market model.

3. Evaluation of over-identified equations by the method of the smallest squares can be stopped at the second step, as it is evidence of the quality of all the stipulated variables.

PROSPECTS FOR FURTHER RESEARCH

The prospects of further research lie in the development of methods of modeling the financial market by means of uniform systems of equations and means of symbolic mathematics.

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