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ECONOMIC AND MATHEMATICAL MODELING IN ECONOMETRICS

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Keywords: econometrics; mathematical economics; statistical model; economic modeling; supply and demand model; regression models, time series models with deterministic trends and systems of simultaneous equations.

Аннотация: В данной статье в качестве примера уравнения регрессии рассмотрена модель спроса на определенный товар в зависимости от его цены и прибыли. При этом особый интерес представляют модели линейной регрессии. В моделях временных рядов особый интерес представляют модели тренда (устойчивых изменений показателей на протяжении длительного периода времени) и сезонные модели, характеризующие устойчивые колебания уровней индикаторов.
Summary: In this article a model of demand for a certain product depending on its prices and profits describe as an example of a regression equation. In the process, of particular interest are linear regression models. In time series models of special interest are models for the trend (steady variations of the indicators over a long period of time) and seasonal models characterizing stable oscillations of the indicator levels.

Introduction. Econometrics is an amalgam (combination) of economic theory, mathematical economics, economic statistics, and mathematical statistics. In field of this science the development of adequate statistical (econometric) models for economic processes is realized on the basis of the relationships between economic variables. Econometrics uses statistical methods for analysis of real economic and statistical data. Econometrics is a subject included into the curriculum of all students specializing in economics. The corresponding academic discipline in econometrics is called the Quantitative Methods of Analysis in Economics. Students can learn the econometric methods of modeling economic processes and systems as well as application of the models for analysis of the cause-effect relations, prediction, and estimation of the economic policy options. The scope of econometric models and methods is constantly expanding. They are now widely used not only in traditional areas such as macroeconomics and financial markets but also in microeconomics for solving the problems of marketing analysis, financial risk management, logistics, etc. This means that studies of econometric models and methods should form an important component of training wide-reference (generalist) economists.

The peculiarities of teaching econometrics to students of different specialties are determined by a level of their basic mathematical training, degree of adaptation of a lecture or practical course to the research tasks most topical for the particular speciality, as well as by the number of academic hours for the discipline. At the present time the relevant foreign and domestic educational-methodical literature as well as statistical and econometric software (English-language application packages Statistica applications, Statgraphics, EViews) is available, enabling one to organize effectively both lecture courses and computer-aided practical training for different categories of students.

The practical training is focused on three types of econometric models (regression models, time series models with deterministic trends, and systems of simultaneous equations) [1].

Econometric modeling is associated with three basic types of statistical data: spatial data, time series, and panel data.

Spatial (cross-sectional) data are obtained from the same types of objects related to the same point of time: for example, data on production, income, interest rates, and the like, measured at the same time.

Time series characterize the economic object at consecutive points of time: for example, quarterly data, data on average wages, income, etc.

Panel data. Panel data include elements of time series and spatial data. As an example of panel data, we can consider 2 series of observations, taking for each of them a time series of other observations.

Main part. In this tutorial, there are three main classes of models: regression equations, time series with deterministic trend, and systems of simultaneous equations. A model of demand for a certain product depending on its prices and profits may be taken as an example of a regression equation. In the process, of particular interest are linear regression models. In time series models of special interest are models for the trend (steady variations of the indicators over a long period of time) and seasonal models characterizing stable oscillations of the indicator levels. Systems of simultaneous equations involve regression equations and identities. At the same time, endogenous variables from other equations and lag values of endogenous variables may act as explanatory variables. It should be noted that there is no way to study econometrics without the use of modern information technologies, without computerized processing of statistical data or grounded computer-aided analysis of the results.

Econometrics represents a specific section of economic and mathematical modeling. Its task is to examine the correlations between quantitative characteristics of economic objects. These correlations are given in the form of mathematical relationships reflecting the economic nature of events, built in accordance with the statements of theoretical economics. The variables included into the model equations are mainly of the two types.

Exogenous (explanatory) variables or factors represent variables with the values specified from outside of a model.

Endogenous (explained or dependent) variables are derived on the basis of a model. The model is used to get the estimates of endogenous variables from the values of exogenous variables.

Lag variables are the variables (exogenous or endogenous), the values of which are considered at different points of time separated by a particular interval (lag). The values of endogenous variables at the preceding points of time may be predetermined or calculated by the model equations. Then these endogenous variables play a role of exogenous (explanatory) ones.

Predetermined variables are the exogenous variables together with their lag values and also the lag values of endogenous variables at preceding points of time used to find the values of endogenous variables at a given point of time.

Simplified model for demand and supply [2]. It is required to describe the demand Y^d, supply Y^s, and the market price P of some goods as a function of the income X. Assuming a linear relation, we have:

$$\begin{aligned} Y^d &= a_0 + a_1 P + a_2 X + \varepsilon^d \\ Y^S &= b_0 + b_1 P + \varepsilon^S, \\ Y^d &= Y^S. \end{aligned} \qquad (1)$$

If the demand for the goods decreases with the growing price, we have $a_1 < 0$. According to the laws of market economy, $a_1 < 0$, $b_1 > 0$.

In this model, the variable X is an exogenous variable, whereas $Y^d = Y^s$ and P are endogenous variables. The terms ε^d and ε^s are random components. The last equality is an identity that reflects the essence of the market price.

Random component (random perturbation, random residue) of an econometric model is identified as a quantity with unknown values, forming a part of the model equation and reflecting the effect due to the unaccounted factors, inaccurate selection of variables and types of relationships between them, errors in derivation of variables, etc. Just the presence of such components is a distinctive feature of econometric models.

Specification of a model is associated with selection of variables for the model, of the type of relationships between them, and of the restrictions on coefficients of the equations specifying these dependences.

The model specification is due to the task of the object study. It is based on the theoretical economics.

In econometric, sociological, and other studies of great importance is the problem of describing the structure of relations between the variables of a system of structural equations, also known as a system of simultaneous equations (SEM). SEM may be constructed differently. For example, in a system of independent equations, each endogenous variable is considered as a function of one and the same set of factors (endogenous variables) or of the variable set of factors. SEM may be a system of recursive equations, when the endogenous variable of one equation acts as exogenous in other equations. In this case, each successive equation gives an expression for the following dependent variable in terms of the dependent variables from the previous equations and by means of the exogenous variables. A model for the labor productivity and output-capital ratio is an example of such a system.

$$\begin{aligned} y_1 &= a_{11}x_1 + a_{12}x_2 + a_{13}x_3 + \varepsilon_{1.}, \\ y_2 &= b_{21}y_1 + a_{21}x_1 + a_{22}x_2 + a_{23}x_3 + \varepsilon_2, \end{aligned} \tag{2}$$

where y_1 – productivity, y_2 – return on assets, x_1 – capital-labor, x_2 – labor power available, x_3 – consumption of materials production.

In general, SEM is a system of interdependent equations, where the same dependent variables in some equations are in the left-hand side, and in other equations they are in the right-hand side of the system. SEM of this type is called the structural form of a model. The structural form of SEM is based on the statements of theoretical economics reflecting the structural relations between the indicators.

Principle of the number of equations for a model resides in the fact that the number of equations equals the number of endogenous variables.

The next stage of the model development is associated with definition of a structural system of equations with respect to the endogenous variables.

Reduced form of a system of econometric equations is defined as a system, where all endogenous variables are expressed in terms of the predetermined variables.

In Example Y^d, Y^s, and P are expressed in terms of X as follows:

$$Y^d = \frac{b_1 a_0 - a_1 b_0}{b_1 - a_1} + \frac{b_1 a_2}{b_1 - a_1} X + \left(\varepsilon^d - \varepsilon^S\right),$$
$$Y^S = \frac{b_1 a_0 - a_1 b_0}{b_1 - a_1} + \frac{b_1 a_2}{b_1 - a_1} X + \left(\varepsilon^d - \varepsilon^S\right), \qquad (3)$$
$$P = \frac{a_0 - b_0}{b_1 - a_1} + \frac{a_2}{b_1 - a_1} X + \frac{1}{b_1}\left(\varepsilon^d - 2\varepsilon^S\right).$$

This is precisely the reduced form of a demand and supply model. The terms $\varepsilon^d - \varepsilon^S$ and $\frac{1}{b_1}\left(\varepsilon^d - 2\varepsilon^S\right)$ are the random residues. Ongoing from the structural form of SEM (system of econometric equations) to the reduced one and conversely, the problem about the uniqueness of correspondence between the forms arises.

Model identification means uniqueness of correspondence between its structural and reduced forms. To illustrate the concept of predetermined variables, let us consider an example of the demand and supply model with lag variables and the Samuelson-Hicks model for business cycle of economics.

Model parameterization is associated with construction of the estimates for the model coefficients (parameters) based on statistical data and description of the properties of these estimates.

The properties of the estimates of coefficients, playing in econometrics a special role, are largely determined by the properties of random components in the equations and, of course, by the properties of predetermined variables. The quality of a model depends on the properties of these estimates.

Conclusion. Verification of a model is termed as checking of the model quality and adequacy. Such checking is performed by means of special tests or for the quality of prediction. In the process of checking for the model quality, some part of the known statistical data is used to be compared to the predicted data which were obtained on the basis of the rest of the available statistical data.

It seems expedient to perform econometric research as a sequence of the main stages: selection of the research object, problem statement and formulation of the goals; collection and preliminary analysis of statistical data; specification of the model; parameterization; verification; using of the results for prediction, decision making, etc.

Reference

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