УДК 378.147:33:51-7

QUANTITATIVE METHODS IN ECONOMICS TRAINING

Margarita Shopova, D. A. Tsenov Academy of Economics – Svishtov, Republic of Bulgaria, e-mail: m.shopova@uni-svishtov.bg

Шопова Маргарита, Хозяйственная академия им. Д. А. Ценова - Свищов, Р. Болгария.

M. Shopova. Quantitative methods in economics training.
The development of modern economic science is inextricably linked with the use of quantitative methods in research. Mathematical knowledge is needed to facilitate the study of economic disciplines at a modern level. This paper focuses on the potentialities of mathematics learning for the economic training of students. It presents different aspects of the application of mathematics in economics and economic research as well as the use of mathematical models. The paper justifies the need for designing an appropriate mathematics course, which will provide future economists with theoretical knowledge and practical skills to solve real business problems.

Шопова М. Количественные методы в обучении экономике.
Развитие современной экономической науки неразрывно связано с применением количественных методов в исследованиях. Для того чтобы стало возможным изучение экономических дисциплин на современном уровне, необходимы математические знания. Предметом публикации являются возможности обучения математике для экономической подготовки студентов. Представлены различные аспекты применения математики в экономике и экономических исследованиях и использования математических моделей. Обосновывается необходимость создания подходящего курса по математике, который поможет будущим экономистам приобрести теоретические знания и практические умения для решения реальных проблем бизнеса.

Introduction

The development of modern economic science is increasingly being characterized by interdisciplinarity. Economic research is inextricably linked to the use of quantitative methods and models. Their use is an important prerequisite for appropriate justification of the theoretical formulations and calculation of indicators for characterizing different aspects of the studied phenomena and processes. Model development not only allows the ongoing processes to be explained, but it is also an opportunity to predict their future development.

The development of modern economic science is inextricably linked with the use of quantitative methods in research. Econometric and mathematical models in economics began to be applied as early as the 18th century, but the experiments continued in the 19th century, as well[1] [10, pp. 3-4]. However, the real expansion of quantitative methods in economics was in the 20th century. This is confirmed by the fact that the establishment of the Nobel Prize in Economics in 1969 was dictated by the desire to stimulate their use for the justification of the theoretical findings and practical applications. These intentions have come to fruition – most of the Nobel laureates in economics have created methods and have applied models, based on mathematics as a fundamental science for all quantitative methods, justification of various economic theories and analysis of phenomena[2] [8].

Mathematical knowledge is needed to facilitate the study of economic disciplines at a modern level. Nowadays, mathematical tools are used in each course of economics, though to a different extent: graphs of different dependencies are analyzed, statistical data is processed in terms of mathematics, etc. With the establishment of market relations, the issue of a rational choice has become basic and each economic entity has to make a choice by making independent decisions. This raises the need for accurate mathematical calculations and leads to an increase in the role of quantitative methods in economics.

The **purpose** of this paper is to present the application of quantitative methods in economic research and to justify the need for developing an appropriate mathematics course,

Slavov, Z. and Evans. Prilozhenie na matematikata v ikonomikata pp. 3-4.
[2] http://www.unwe.bg/bg/pages/2864/nobelova-nagrada-po-ikonomika.html

which is to provide future economists with theoretical knowledge and practical skills in solving real business problems.

I. Application of mathematics in economics and economic research

There is no doubt that in a number of practical areas (organization of production and supply, operation of transport, personnel allocation, healthcare, communications, computing equipment) there are tasks that are similar in terms of formulation, have a number of common features and can be solved by using similar methods. There is a wide range of well-known and some lesser-known economic issues, for whose explanation and solving the economic science relies exclusively on mathematical concepts and methods. Some of these are[3] [1, 3, 5, 7, 11, 12]:

- **Leontief's cross-industry balance model** (Nobel Prize in Economics in 1973 for his contribution to the input-output analysis). An economy consists of n sectors, which are supposed to produce one kind of basic output, and each type of output is produced by only one sector. The output of each sector, except for own (domestic) consumption, is also used as a resource by the other sectors. The relationships between the separate sectors are described through the direct cost matrix (the amount of output of each sector used in the production of a unit of output by the other sectors). The amounts of end-products intended for public consumption are also known. Determining the amount of total output for each of the sectors is limited to solving a matrix equation. The distribution of total output by economy sectors can be found by multiplying matrices.
- **Break-even analysis**. It is an illustration of the application of linear and square functions for describing economic phenomena. In order to fix the break-even point, the graphs of the functions of total costs (a straight line) and total revenue (a straight line at a volume of output argument or a parabola at a cost of output argument) are drawn towards the same coordinate system to determine their intersection.
- **Marginal analysis**. It is the application of differential calculus in economics. It has developed as a natural outcome of studying the issues of economic entities' decision-making. The main assumption here is that consumer interests require that decision-making should be based not only on the information resulting from the absolute data (general and average quantities) but also on the information provided by the marginal values. Tasks solved by marginal analysis are about the functional dependence between the average and the respective marginal value (in order for the average value to increase, the marginal value should be greater than it), the costs (earnings, profit) in producing an additional unit of output, and the change in average earnings (costs, profit) with minor changes in production volume or cost of production, etc.
- A 'golden rule' in economy is that hiring an additional worker in a company is profitable only if his/her contribution is greater than his/her salary. The proof of this fact is based on the notion of **derivative of a function** (the production function is considered at an argument regarding the number of staff).
- **Point of diminishing returns**. It reflects the limit beyond which the additional input of resources does not lead to a proportional increase in income. The mathematical concept which illustrates this phenomenon is the inflection point of the revenue function.
- **Elasticity coefficient**. In economy, it is most often used to study the relationship between the demand for a commodity and its price. Depending on the values of this coefficient, there is elastic, inelastic or neutral demand. The meaning of this concept becomes much clearer if its mathematical definition is known – a relative derivative. It characterizes

[3] B a n n o c k, G., R. Baxter, E. Davis. Svetoven rechnik po ikonomiks [International Dictionary of Economics]. Burgas, Delfin pres, 1992; B l a g o e v, B. i M. Bliznakov. Mikroikonomika. Varna, sdruzhenie "AL", 1992; V ye n t ts ye l ', YE. S. Issledovaniye operatsiy. Zadachi, printsipy, metodologiya. Moscow, Nauka, 1988. M a l y kh i n, V. I. Matematika v ekonomike. Uchebnoye posobiye. Moscow, INFRA-M, 2000; S m i t h, A. Matematichesko vavedenie v ikonomikata [A mathematical introduction to economics]. S., UI "Sv. Kl. Ohridski", 2000; S o l o d o v n i k o v, A.S., V. A. Babaytsev i A. V. Brailov. Matematika v ekonomike. Uchebnik (v dvukh chastyakh). Moscow, Finansy i statistika, 2000.

the approximate percentage change of the dependent variable when the argument changes by 1%.

- **Complementary, interchangeable and unrelated products**. If their demand functions are known (functions of two variables), the signs of their partial derivatives can accurately determine the relationship between the studied products.
- **Cobb-Douglas production function**. It measures the volume of the end product according to the input units of labour and capital. In order to evaluate the effectiveness of the change of either factor, a marginal analysis of a function of two variables is used.
- The role of the *least squares method* in economics is invaluable and undeniable in deriving the analytical type of the functions that **model trends or dependencies** in the studied economic phenomena.
- **The value of one basket of consumer goods.** It can be determined by the *scalar product of two vectors* – the quantities of the goods included in it and their respective prices are considered vectors. The rationality of such an approach is proved when electronic computing equipment is used.
- **Budget constraint**. To describe the different possibilities of an individual to consume goods from two (three) consumer baskets at a given disposable income, the *equations of a straight line in the plane (plane in space*) are used.
- **Rational allocation of resources**. An enterprise has secured its production activity with certain amounts from several resources. The costs of resources for the production of a unit quantity of each item included in the production list of the enterprise are also known. Under certain performance indicators (earnings per unit, average unit cost, etc.), the development of an enterprise production programme providing optimal performance is required. The problem is solved by developing a linear optimization model.
- **Distribution task.** Several enterprises use the same type of a raw material that can be delivered by several warehouses (production bases). The cost of transporting a unit quantity of the raw material between the warehouses and enterprises is known. A supply plan has to be developed ensuring the need for a raw material, with minimum transportation costs. In order to solve the task, an algorithm known as 'transport task' has been developed.
- Graphic images are one of the main ways of presenting statistical information that contribute the most to the clearness of presentation. They can be used to successfully illustrate the demand and supply curves, as well as the economic equilibrium. Knowing the graphs of the basic elementary functions, the ability to 'read' the graph of a function and to draw conclusions about its properties contributes significantly to the successful modelling of the studied economic phenomena.
- Faced with the problem of making a decision with accurate and clear justification, economists need the tools of financial mathematics to ensure the accuracy and precision of financial calculations. Besides, knowledge of financial mathematics is necessary in studying a number of economic disciplines, such as finance theory, bank and budget accounting, etc.
- The theory of strategic games, probability theory, mathematical statistics, the theory of statistical decisions, etc. are used as mathematical tools for decision-making under the conditions of uncertainty and risk.
- There are other applications of mathematics in economics – the models of Keynes's static equilibrium, Schumpeter's dynamic equilibrium, analysis of demand-supply interactions and Walras's influence of prices, Kantorovich's optimal planning, etc. Differential equations are a basic method for compiling dynamic economic models, applied for optimal production inventories, optimal organization of production, etc. Power series and Fourier series are used to examine time and statistical series. Finding conditional extrema of multi-variable functions underlies the tasks for optimizing different processes.

II. The use of mathematical models in economic research

Economic-mathematical models are the theoretical basis and practical tools for analyzing and forecasting the solutions in economy and businesses. Mathematics is a natural science because it arose as a result of the need to accurately describe the reality surrounding humans. Along with that, it is a fundamental and abstract science because it provides knowledge necessary and useful to the other natural sciences and humanities. The models created by mathematics and the methods developed for studying them can be adapted by other sciences. In other words, mathematics is an independent science that has its world-wide significance, but for scientists from different scientific fields (including economists), it is largely a tool for analysis and management.

The modelling method is based on the principle of analogy, i.e. on the possibility to study a complex real object not directly, but through a similar and accessible object called a model. When creating a mathematical model, the real phenomenon is inevitably simplified, schematized, and this pattern is described via mathematical tools. The danger here lies in turning the real object into a simplified copy. On the other hand, we would like to 'transfer' the conclusions drawn in studying the model to the real object. Therefore, the model should reflect the essential features of the object studied. If such duality exists, modelling is an art. The more appropriately a mathematical model is chosen, the more successful the study and the more useful the recommendations arising from it will be.

There are no general rules for developing a mathematical model. In each specific case, the model is selected according to the phenomenon studied, taking into account the tasks of the study – what parameters should be determined and the influence of what factors should be covered. Creating a mathematical model is the most important and responsible part of the study. It requires in-depth knowledge not only in the field of mathematics but also regarding the modelled phenomenon. As a rule, a 'pure mathematician' would fail to create the model without the help of a specialist in the field of the phenomenon studied. Experience has shown that the most appropriate models are created by specialists in the specific scientific field, who have sound, in-depth mathematical training or by teams bringing together practitioners and mathematicians.

The significant advance in mathematical theories (linear algebra, mathematical analysis, probability theory, correlation and regression analysis, differential equations, etc.) provides very powerful and developed mathematical tools. In order to use the mathematical approach in economic research, the fact that mathematics cannot operate with imprecise and unclear definitions should be taken into account. Therefore, the task, including all the assumptions made, needs to be formulated accurately from the very beginning.

The application of mathematics in economy allows for experimentation. The immediate verification of some theories often involves significant costs or losses. The modelling of economic phenomena allows for checking the effect of one or another proposal or assumption repeatedly, at minimal costs and with minimal risk. On the other hand, mathematical methods are only a means of obtaining a solution to a task set by the economy. A satisfactory solution to the task can be obtained from true and accurate assumptions. In other words, mathematics gives true and accurate solutions, but is not a criterion for the veracity of the solution to the economic task. To get the right solution, a problem needs to be clearly formulated by an economist specializing in the respective field.

In order to successfully deal with the modelling of modern economic processes, a specialist must have knowledge both in the classical sections of mathematical analysis and in the relatively new sections of mathematics such as linear, nonlinear and dynamic programming, game theory, mass-service theory, etc. Special emphasis should be placed on the need for knowledge in probability theory. This specific need is explained by the fact that most of the economic phenomena and processes are carried out under the conditions of uncertainty and risk and their development depends on a number of random factors. The probability theory allows for a suitable transformation of information by making conclusions about data on phenomena that are unavailable for observation from phenomena that are available.

The training of economics students should comply with the need for creating specialists in line with the contemporary needs of the information society. Along with this, the expansion of computers imposes special requirements on the knowledge of mathematics. Last but not least, it should be taken into account that the fundamental preparation (part of which is the knowledge of mathematics) has to meet European and world standards. For this reason, one of the main tasks in the training of students in economic specialties should be the creation of skills and habits for using, solving and analyzing mathematical models imitating real economic phenomena and processes.

There is no unambiguous opinion on what and when to learn. Very often, there are extremes. In terms of the topics covered, the main weakness of the curricula is their universality and non-compliance with the specific theoretical and practical problems of the particular specialty. On the other hand, the teaching of 'pure' mathematics and the trend to demonstrate the deductive structure of mathematical knowledge – with strict definitions of concepts, proofs of statements, purely mathematical tasks, without applications in economics, provoke negative attitudes in learners. Concepts can be descriptively defined, strict theorem formulations and their proofs can be left out, but then – they can be richly illustrated by means of graphs or examples from the field of economics. The availability of various software products that can be used to solve basic tasks (determinants, matrix multiplication, simplex method, etc.) allows for reducing the volume of topics related to the use of computational procedures and to emphasize the interpretation of the results obtained after the application of the relevant method. It is appropriate for the axiomatic approach of presenting a concept to be replaced with an intuitive one, to clarify the logical link between the individual statements, to show particular practical applications with examples; where possible, different mathematical concepts and statements to be illustrated with economic concepts, the terminology used should be consistent with the depth of economic knowledge reached by students through courses already attended in economic disciplines; the theoretical formulations should be made from particular practical situations, which motivates the necessity of using mathematical methods.

Conclusion. Nowadays, there is a proven need for creating new economic employees with new qualities, among which mathematical competence takes an important place. The result of economics training is that employees have acquired knowledge, skills and qualities, which are a prerequisite for successful realization in the labour market. Mathematical competence also contributes to this. In order to be able to solve the problems arising in practice, to be precise, of principle and pedantic not only in their requirements but also in the fulfillment of their professional commitments, a future economist must be able to involve mathematical knowledge as a mandatory element in their general knowledge.

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Ключевые слова: *количественные методы в экономике; применение математики в экономике; обучение экономистов математике.*
Keywords: *quantitative methods in economics; application of mathematics in economics; mathematics training for economists.*

Рецензент: *Anastasiya Marcheva, Associate Professor, Ph.D., Strategic Planning Department D. A. Tsenov Academy of Economics, Svishtov, Bulgaria*

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