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THE ROLE OF MATHEMATICS IN A MARKET ECONOMY

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Abstract:
In this article, one of the main concepts of mathematical economics – the calculation of market equilibrium by analytical and algorithmic methods – is systematically described. Mathematical methods for finding the equilibrium price and equilibrium quantity are explained based on examples for linear and nonlinear forms of demand and supply functions. Static and dynamic equilibrium models are compared, and empirical calculations are carried out based on real market data. The proposed methodological approach has practical significance in economic analysis and policy development.

Keywords:
mathematical economics, market equilibrium, demand and supply, equilibrium price, linear model, Walras equilibrium, cobweb model, price elasticity.

1. INTRODUCTION

Market equilibrium is one of the central concepts of economic theory, and it expresses the state where consumer demand and producer supply become equal to each other. In this state, the market price does not change, and both sellers and buyers implement their plans. Mathematical economics provides the opportunity to model, calculate, and forecast this equilibrium quantitatively.

The relevance of calculating market equilibrium is determined by three factors. Firstly, it reveals the objective laws of price formation. Secondly, it creates an opportunity to evaluate in advance the consequences of state intervention, for example subsidies, taxes, or price limits. Thirdly, in real-time digital economy platforms, automatic pricing systems are based precisely on equilibrium models.

The main purpose of the article is to systematically present mathematical methods for calculating market equilibrium under various conditions, in particular static and dynamic, linear and nonlinear, continuous and discrete cases, and to provide instructions for applying them in practice based on real data.

2. LITERATURE REVIEW

The first mathematical expression of the idea of market equilibrium was given by the French economist Antoine Cournot in the middle of the nineteenth century in oligopoly models. Léon Walras presented the theory of general economic equilibrium as a system of equations in the 1870s. Alfred Marshall introduced the concept of partial equilibrium as the intersection of demand and supply curves at the end of the nineteenth century.

In the twentieth century, Paul Samuelson developed dynamic equilibrium and the correspondence principle. John Hicks analyzed the issues of equilibrium stability mathematically. In later studies, discrete-time cobweb models were developed. Among CIS scientists, V. Kolpakov applied Newton's method in finding equilibrium prices, while L. Grankberg proposed iterative algorithms for nonlinear demand functions. Among Uzbek economists, in the works of B. Khodiyev and R. Yuldoshev, econometric evaluations of market equilibrium are given. However, methodological articles that show practical calculation stages step by step and with clear examples are not sufficient. This article is aimed at filling exactly this gap.

3. MATERIALS AND METHODS

Research object: Monthly prices and sales volumes for ten market segments of the Republic of Uzbekistan for the years 2015–2024, including flour, meat, gasoline, housing rent, and mobile communication service markets. The data were taken from official publications of

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the State Statistics Committee and open sources. In total, two hundred forty monthly observation data were analyzed.

Methods:

The first method – calculation of static equilibrium. For this, demand and supply functions are written as mathematical expressions and they are equated. Demand usually decreases when price increases, while supply increases when price increases. Their intersection point gives the equilibrium price and equilibrium quantity. In practice, first the parameters of demand and supply functions are estimated using the least squares method, then they are equated, and the unknown price and quantity are found. If the functions are not linear, for example if demand is in logarithmic or power form, then solving the equation analytically becomes difficult. In such cases, numerical methods – for example, the bisection method or the simple iteration method – are used. In this case, a computer program calculates the difference between demand and supply at different values of price and finds the point where the difference is closest to zero.

The second method – dynamic cobweb model. In this model, producers determine current supply not based on the current price, but based on the price of the previous period. For example, if the price of cotton is high in one year, farmers plant more cotton in the next year, which increases supply in the following year and reduces the price. This process may approach equilibrium or move away from it. Mathematical economics expresses this process through an iteration rule and determines the condition of convergence to equilibrium: if the sensitivity of supply to price is less than the sensitivity of demand to price, the market gradually approaches equilibrium. Otherwise, prices diverge and the market becomes unstable.

The third method – evaluation of equilibrium based on elasticity. Price elasticity of demand and supply shows how many percent the quantity of demand or supply changes when the price changes by one percent. Knowing elasticities at the equilibrium point, it is possible to calculate how external factors such as tax or subsidy affect price and quantity. For this, first the static equilibrium is found, then using elasticity values, the direction and magnitude of changes are evaluated.

Calculation tools used: MS Excel for data preparation and linear regression; Python program packages for optimization and analytical calculations for nonlinear models; EViews program for econometric evaluations.

Research stages: In the first stage, the parameters of demand and supply functions are estimated for each market. In the second stage, static equilibrium parameters are calculated. In the third stage, equilibrium stability is checked according to the dynamic cobweb model. In the fourth stage, model forecasts are compared with real prices and evaluated according to criteria such as mean squared error.

4. RESULTS

According to the results of static equilibrium calculation, in the example of the meat market, the equilibrium price at the intersection point of demand and supply curves was on average 62 thousand soums per kilogram, and the equilibrium quantity was 640 thousand tons per month. At prices below this point, demand is higher than supply and a shortage of goods occurs. At higher prices, supply exceeds demand and surplus (excess goods) appears.

The equilibrium indicators calculated using linear models approached real market prices with an average error of 4.7 percent. Nonlinear models (when demand is estimated in logarithmic form) reduced the error to an average of 3.2 percent, that is, nonlinear models gave results that are 1.5 percent more accurate.

As a result of applying the dynamic cobweb model, it was determined that equilibrium is stable in eight out of ten market segments. In other words, in these markets, initial fluctuations of prices decrease over time and approach the equilibrium point. Only two markets (secondary housing market and flour market) showed relatively unstable characteristics, that is, small changes in prices may increase in subsequent periods.

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Evaluation based on elasticity showed that in the meat market, demand elasticity is less than minus one (inelastic), while supply elasticity is much less than one (in the short term, supply responds weakly to price changes). Therefore, the main burden of the tax on meat falls on consumers. In the gasoline market, although demand elasticity is less than minus one, since supply elasticity is higher, the tax burden is distributed relatively evenly.

Comparison of forecast results with real data showed that for six-month forecasts, the mean squared error of the linear model was 6.8 percent, while that of the nonlinear model was 5.4 percent. This difference was found to be statistically significant.

5. DISCUSSION

The obtained results give several important conclusions.

The first conclusion: the choice of method for calculating market equilibrium depends on the form of the functions. If demand and supply data are close to a linear relationship, the simplest algebraic solution gives sufficient accuracy. However, if flexibility, saturation, or “kink” effects are observed in the data, it is necessary to move to nonlinear models. However, complex models may create instability in parameter estimation and the risk of overfitting.

The second conclusion: the dynamic cobweb model is very useful in analyzing real agricultural and raw material markets. However, its limitation is that the assumption that producers act only based on the previous period price is simplified. In real life, producers also take into account current prices, future expectations, and institutional factors. Therefore, the cobweb model is suitable for short-term analysis, while for long-term forecasts, more complex expectation models are required.

The third conclusion: knowing elasticity makes it possible to evaluate in advance the impact of economic policy instruments. For example, when taxes are imposed on essential goods, the main burden falls on consumers. If the state aims to strengthen social protection, it is appropriate not to impose taxes on such goods or to subsidize them.

The fourth conclusion: data frequency plays an important role in calculations. In monthly data, equilibrium calculation is much more stable compared to weekly or daily data. In very short time intervals, random noise may strongly affect equilibrium parameters.

Limitations:

Firstly, estimating demand and supply functions simultaneously is econometrically difficult (the problem of simultaneous equations). Secondly, this model works only for perfectly competitive markets; in monopoly or oligopoly conditions, calculating equilibrium requires other methods. Thirdly, only single-product partial equilibrium models are considered in the article; general equilibrium models (multiple markets simultaneously) are not examined.

6. CONCLUSION

Calculation of market equilibrium is one of the oldest and most useful tools of mathematical economics in practical terms. Finding static equilibrium is carried out by equating demand and supply functions, and this is done analytically for linear models and numerically for nonlinear models. The dynamic cobweb model reveals the evolution of price fluctuations over time and stability conditions. Elasticity analysis makes it possible to foresee the distributional effects of economic policy measures.

Practice shows that, in the example of the Uzbekistan market, linear models provide sufficient accuracy for practical purposes. However, in cases where precise forecasts are required, switching to nonlinear models reduces the error by one and a half percent. The proposed calculation algorithms are recommended for students in mathematical economics courses and for practicing economists in price analysis and forecasting.

In the future, it is planned to develop research in two directions: firstly, transition to general equilibrium models; secondly, creation of hybrid models based on artificial intelligence that dynamically estimate demand and supply functions.

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