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GENERAL ECONOMIC EQUILIBRIUM MODELS

МОДЕЛІ ЗАГАЛЬНОЇ ЕКОНОМІЧНОЇ РІВНОВАГИ

The article examines the possibilities and limitations of empirical models of general economic equilibrium and makes their classification. Computable general equilibrium models are divided into two groups: the first group is based on the equilibrium price model (G. Scarf's approach), the second is based on a multi-sectoral model of economic growth (L. Johansen's approach). Dynamic stochastic general equilibrium models are also divided into two groups: the first group is based on the model of the real business cycle (the approach of F. Kydland and E. Prescott), the second is based on the model of various behavior of firms in conditions monopolistic competition (the approach of J. Rotemberg and M. Woodford). Within each group, empirical models were studied according to the following criteria: the scale of the economy, its openness; application for current and future assessments; socio-economic phenomenon under study.

Key words: *classification, general economic equilibrium, applied general equilibrium, computable general equilibrium, dynamic stochastic general equilibrium.*

У статті розглянуто можливості та обмеження емпіричних моделей загальної економічної рівноваги, здійснено їх класифікацію. Класифікація емпіричних моделей проведена для кожного традиційного типу моделей загальної економічної рівноваги – обчислюваних та динамічних стохастичних. Моделі обчислюваної загальної рівноваги поділені на дві групи: перша група заснована на моделі рівноважних цін (підхід Г. Скарфа), у якій побудований простий приклад глобальної нестійкості ринкової рівноваги, друга – на мультигалузевій моделі економічного зростання (підхід Л. Йохансена). Аналіз масиву емпіричних моделей дозволяє стверджувати, що основна частина моделей загальної рівноваги першої групи, що обчислюється, застосовується для поточних оцінок функціонування бюджетної системи закритої національної економіки; моделі другої групи – для поточних та довгострокових оцінок стану відкритої субглобальної та національної економіки у межах різних інтеграційних процесів. Моделі динамічної стохастичної загальної рівноваги також розділені на дві групи: перша група заснована на моделі реального бізнес-циклу (підхід Ф. Кідланда та Е. Прескотта), друга – на моделі різної поведінки фірм в умовах монополістичної конкуренції (підхід Дж. Ротемберга та М. Вудфорда). Моделі динамічної стохастичної загальної рівноваги першої групи застосовуються головним чином для середньострокових оцінок макроекономічних процесів функціонування глобальної та національної економіки; моделі другої групи – для поточних та короткострокових оцінок стану глобальної, субглобальної та національної економік за умов шоків на галузевих та фінансових ринках. У межах кожної групи зроблено розмежування емпіричних моделей за такими критеріями: масштаб економіки, її відкритість; застосування для поточних та перспективних оцінок; досліджуване соціально-економічне явище. При використанні моделей загальної рівноваги в прикладних дослідженнях, необхідно враховувати, що незважаючи на численні спроби, не вдалося знайти скільки-небудь загальні та природні умови, що забезпечують єдиність і стійкість рівноваги.

Ключові слова: *класифікація, загальна економічна рівновага, прикладна загальна рівновага, обчислювана загальна рівновага, динамічна стохастична загальна рівновага.*

Formulation of the problem. There is a need to classify empirical models for each traditional type of general economic equilibrium model – computable and dynamic stochastic. Also, within each group, distinguish between empirical models according to the following criteria: the scale of the economy, its openness; application for current and prospective assessments; the studied socio-economic phenomenon.

Analysis of recent research and publications. The hypothesis about the existence of general economic equilibrium was originally set out in the work of L. Walras. Pure political economy was conceived by Walras as a theory of price determination under a hypothetical regime of free competition [1-2]. The author argued that "...this theory is mathematical, which means that although it can be stated in ordinary language, its proof must be mathematical. It is entirely based on the theory of exchange, which, in turn, is entirely expressed – in a state of market equilibrium – in a double fact (the central idea of the theory of general equilibrium): firstly, the fact that each participant in the exchange receives maximum utility, and secondly, the fact that the volumes of demand and supply for each product are equal for all participants. Only mathematics can give us the condition for maximum utility." These two facts underlie the equilibrium state in markets, according to L. Walras. If the first fact defines equilibrium as the state of each individual economic entity, then the second fact fixes equilibrium as the state of the system of interacting entities as a whole. As new research appears, theoretical explanations (algorithms) of general economic equilibrium inevitably become more complex, incorporating approaches from related disciplines: game theory, algebra and linear programming [2-3]. General economic equilibrium models are actively used as an applied tool in analyzing the effectiveness of economic policies, as well as the influence of various types of impacts on the economy at various levels [4]. General equilibrium models used to obtain quantitative estimates are divided into two types: computable and dynamic stochastic.

Formulation of the purpose of the article. The purpose of this study is to systematize existing empirical models within the framework of the general equilibrium approach. The array under study included empirical studies covering the time period 1950–2014.

Presenting of the main material. *Empirical computable general equilibrium models*. Empirical computable general equilibrium models involve the use of econometric methods, namely the solution of a system of nonlinear equations, as a result of which it is possible to achieve an equilibrium of supply and demand in the markets of goods, services and factors of production. Variables are differentiated into exogenous and endogenous. Each new endogenous variable is associated with constraints that may reflect market equilibrium conditions, and then a fitting or calibration procedure is performed. Equilibrium is achieved through iterative recalculation. Computable general equilibrium model algorithm comes down to obtaining, through calibration, a system of balance equations that describe the connections and behavior of economic agents [5-7]. Depending on the type of the initial model, empirical computable general equilibrium models can be divided into two groups: the first group is based on the equilibrium price model (G. Scarf's approach), the second – on a multi-sectoral model of economic growth (L. Johansen's approach).

First group of computable general equilibrium models. Is based on an algorithm for calculating price equilibrium for the general economic model of exchange, proposed by G. Scarfe [8-9]. The algorithm is based on the fixed point theorem, game theory and the simplex method of optimization problem of linear programming [3-4]. These models are referred to as applied general equilibrium models. The object of study of the first group of computable general equilibrium models is mainly fiscal policy in a static, closed national economy. Within the first group of models, estimates are constructed for an open economy from the point of view of finding the optimum between the level of customs duties and budget expenditures.

The second group of computable general equilibrium models is based on L. Johansen's algorithm [10] using V. Leontiev's input-output tables, as well as social accounting matrices.

L. Johansen's model, including R. Solow's production functions and R. Frisch's consumer demand functions, was built for the Norwegian economy and was called the Multi-Sectoral Growth Model. In this model, the production of each sector is represented as a Cobb–Douglas function for capital and labor with neutral technical progress, and consumption includes a full set of expenses as direct and cross price elasticities, according to the Frisch methodology. [11-12]. The model includes a lot of endogenous and exogenous variables and is considered the first Computable General Equilibrium Model, based on a system of reduced equilibrium balances of factors, goods, budget equations and price equations.

L. Johansen's computable general equilibrium models, in addition to Cobb–Douglas functions, can include functions with constant elasticity of substitution. They assume that, first, the elasticities of substitution in each market are constant. Second, the elasticity of substitution between any two competing products in a market is the same as between any other pair of competing products in the same market. Also, functions of constant elasticity of transformation are used, which are a consequence of a function with constant elasticity of substitution. Where the production capabilities of a firm (industry) depend on various combinations of production activities. General economic equilibrium is calculated using specialized application packages.

Empirical models of the second group, compared to the models of the first group, are the most numerous and are used to assess the behavior of an open economy at the global, subglobal and national levels. Endowing computable general equilibrium models with dynamic properties becomes possible by including intertemporal optimization processes in the models. The results of solving these models are equilibrium trajectories or periods, which are an iteration step, as in a static computable general equilibrium model.

Projections of the global and sub-global economies are made using both GTAP statistics and data from other sources. A long-term model of global economic development was developed at the French Center for the Study of International Economics. The model describes the development of 128 world economies until 2050 according to two key parameters – energy efficiency (described by the constant elasticity of substitution function) and total factor productivity (Cobb-Douglas function for labor and capital). The model specifies the behavior of the real exchange rate, which determines the growth of factor productivity of national economies. This study can be considered as an example of assessing the impact of technological development on a national or global economy. In terms of the breadth of coverage of the study of socio-economic phenomena or processes, the empirical models of computable general equilibrium of the second group significantly exceed the models belonging to the first group. The bulk of empirical models of the second group are aimed at assessing the effects of foreign economic liberalization.

Empirical models of dynamic stochastic general equilibrium. The need to create a separate type of general economic equilibrium models was determined by the need to carry out forecast estimates. This type of models began to be designated as dynamic stochastic general equilibrium models (Dynamic Stochastic General Equilibrium) [13]. To estimate dynamic stochastic general equilibrium models, classical econometric approaches are used (generalized method of moments, least squares method, maximum likelihood method, etc.), vector autoregression models and the Bayesian approach, which involves the use of tools from probability theory. The use of the Bayesian approach makes it possible to: apply rigor in some areas with flexibility in others; use information from different sources and generate missing information, use autoregression to make prospective estimates [14]. The utility maximization conditions for all agents and the equilibrium conditions for all markets impose restrictions on possible interactions between variables and establish functional dependencies between coefficients [7].

Models of dynamic stochastic general equilibrium can be divided into two groups: the first group is based on models of the real business cycle (the approach of F. Kydland and E. Prescott), the second is based on models of variable behavior of a firm in conditions of monopolistic competition (approach J. Rotemberg and M. Woodford).

The first group of dynamic stochastic general equilibrium models is based on the theory of the real business cycle within the framework of the approach of F. Kydland and E. Prescott [15]. Researchers (for the US economy) took into account the lag of some indicators from others, as well as the dependence of indicators on their past values.

Empirical models of the first group are used to obtain comprehensive assessments of the impact of external and internal factors on the national economy. One of the most complex models, including more than a thousand variables, is the BEQM (Bank of England Quarterly Model), based on the results of which short-term macroeconomic estimates of the UK are published annually. The model is based on national accounts data from the second quarter of 1992 and describes the behavior of agents in the domestic private sector, the state and abroad, as well as their interactions in the capital, goods, labor and financial markets. The model assumes the state of the condition for all expenses in the long term and assumes the behavior of agents in the market under conditions of long-term expectations. Currently, the Bank of Great Britain uses a model whose core is a dynamic stochastic general equilibrium model based on the Bayesian approach to obtain prospective estimates of the development of the national economy. The model contains algorithmic constraints and internally consistent predictions. Prices and wages are not free, and monetary policy determines production and employment in the short to medium term. Empirical models of the first group are used to assess inflation trends.

The second group of dynamic stochastic general equilibrium models is based on a model of different behavior of firms in conditions of monopolistic competition (the approach of J. Rotemberg and M. Woodford) [16]. This approach involves determining current and short-term estimates. Empirical models used to generate current estimates tend to be quite simplistic.

Short-term estimates are constructed mainly by leading international organizations, central banks and specialized institutions. For example, short-term assessments of the development of the global economy are carried out by the IMF within the framework of the Global Integrated Monetary and Fiscal Model. This model was developed to assess the consequences for the world economy from the implementation of stimulating effects by the leading countries of the world in the context of the global crisis of 2008. The model is based on modeling the behavior of entrepreneurs and the banking sector in conditions of external demand shock and changes in monetary policy. The model separately generated a block that simulates the behavior of prices in the commodity sector with low values of elasticity of substitution, the main parameter of which is oil prices. The behavior of the consumer, investment sectors, as well as the wage fund is also modeled. Elasticities of substitution and coefficients of utility functions in the model are given exogenously from other IMF studies. Households are characterized by forward-looking expectations, i.e., they are guided by the government's budget constraint when making consumption decisions. This results in patterned government spending not influencing agents' consumption decisions, and thus not changing aggregate demand. This hypothesis is used as an argument against tax cuts aimed at increasing aggregate demand.

The European Central Bank model is used to obtain a short-term assessment of an open sub-global economy – for a grouping of countries that have adopted a single currency – the euro. This model estimates 18 macroeconomic variables, including: GDP, private consumption, investment, public sector consumption, exports and imports, various deflators, employment and wages, interest rate, effective exchange rate, foreign demand for the euro, oil prices. The statistical series in the model has been formed since 1985 and consists of quarterly data. The same model is given as an example for assessing inflation trends.

The second group of empirical models makes a short-term assessment of an open national economy. The model contains a separate block showing the functioning of the external market. Pricing in the model is carried out under conditions of monopolistic competition. There are models that estimate the short-term consequences of domestic macroeconomic policy shocks.

The US Federal Reserve Administration uses the Estimated Dynamic Optimization-based Model for a comprehensive assessment of external and internal factors on the country's economy. It is based on the probabilistic approach of Markov chains and the Monte Carlo method and includes more than two hundred statistical indicators for quarters since 1984. It models the development of the American economy according to the following main indicators: GDP growth, consumer spending on services and on non-durable and durable goods, investment in manufacturing and housing construction, consumer price index for various goods, inflation in the manufacturing sector, labor costs, growth wages, federal funds interest rate.

Conclusions. General equilibrium models have become widespread in applied economic research, largely due to the fact that they make it possible to quantify the relationships between various parameters of the economic system, as well as the impact of various factors. When using general equilibrium models in applied research, it is necessary to take into account that, despite numerous attempts, it was not possible to find any general and natural conditions that ensure the uniqueness and stability of equilibrium. It is still not possible to find out their specificity, and without this, answers to many fundamental questions of the theory cannot be obtained.

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