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Application of Selective and Optimal Control to Achieve Turnpike Growth Rate

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Abstract

The paper sees into the problem of bringing a certain macroeconomic system to the turnpike line of development along the trajectory, which, in terms of some quadratic quality criterion, approximates the proportions of gross output to optimal ones. Moreover, optimal proportions of gross output are considered to be the proportions of the turnpike economic system. A turnpike system is formed due to a selective control of the final demand vector, thanks to which the final demand vector becomes balanced. Optimal control of a developing microeconomic system allows achieving turnpike growth rates of a master system in the fastest way possible. The basis is an input–output dynamic model between the branches that was developed by Wassily Leontief. Selective control is based on interrelation of dynamic module secular equation roots and variable parameters, which are, in these terms, elements of the final demand vector. An objective of optimal control in this paper is formation of a linear-quadratic regulator, which can help to bring a certain microeconomic system on the trajectory of the already existing turnpike system. The use of qualitatively new principles of selective control in order to analyze and manage the balanced growth of gross output makes it possible to influence the specified movement components of dynamic macro-systems. Such inclusion of economic and mathematical methods in the objectives of state regulation of microeconomics is worth being considered as the most prospective.
When applying methods of selective and optimal control of final demand and external investment effects on microeconomic systems it is possible to create and maintain turnpike growth rates of these systems, analyze and optimize temporary investment processes in the phase space of industries and provide financial and economic information about costs and investments for decision-makers in terms of optimal economic development.

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1. Introduction

Optimal control in macroeconomic systems is a serious task, which can be solved at minimum costs to update (Babkin, Kudryavtseva, Utkina 2013; Vertakova, Grecheniuk, Grecheniuk 2015) economy fundamentally. Update is crucial for a balanced growth of gross output, GDP and other microeconomic indices (Toroptsev, Tatochenko 2011).

The dynamic input-output model of W. Leontief, which is a system of ordinary differential equations, is a formalized mathematical and statistical basis that can be used to construct automated methods of economic dynamics analysis and management. Today a model approach can be seen as a practically irreplaceable means of systematic study of functioning or malfunctioning of the modern economy, searching for potential or actual sources of such violations and defining ways to eliminate them. One of the directions that help to considerably increase the quality of impact on gross output growth rates is selective control.

In this work (Leontieff, 1951) we see the Leontief dynamic input-output model, which has the following generally accepted appearance:

$$(E - A)\, X(t) - B\, \dot{X}(t) = \Psi(t) \tag{1}$$

where A – coefficient matrix of direct costs; X(t) – gross output vector-function; B – increment capital coefficient matrix; Ψ(t) – final demand vector-function; E – identity matrix.

Selective control (Babkin, Kudryavtseva 2015) is based on interrelations of secular equation roots of the input-output model (1) with variable parameters, which, in this context, are elements of the final demand vector Ψ(t). If all the roots are negative, then the output parameters of an economic system are declining. In cases there are positive roots in the input-output model, driving competition of industries is witnessed. One positive root ensures a constant and balanced growth of turnpike development for the microeconomic system. Application of selective control to the final demand vector makes it possible to form such a dynamic system, whose path dependencies will be balanced.

An objective of optimal control in this paper is formation of a linear quadratic regulator, which makes it possible to bring a certain macroeconomic system to the path dependences of the already formed turnpike system.

2. Application of selective control to form turnpike

It was Paul A. Samuelson (Samuelson, 1995) who suggested calling any balanced path with a maximum growth rate as turnpike. As a result there appeared an everyday interpretation of achieving economic objectives in an optimum way, i.e.: “to make it” from the initial point X_0 to the final point X_k in the best way possible it is worth to get fast to the turnpike (improved road for fast traffic), “follow” it as long as possible and only at the end turn to the target point. Samuelson’s hypothesis implies that the strategy of an efficient long-term economic growth is similar to the following movement plan: going out of the historically established initial condition, economy, first, has to achieve the maximally balanced growth, then function during as many planned periods as it is possible in the mode or almost in the mode of balanced growth – close to the turnpike, and then, finally, turn to reach a certain objective.

The essence of the method is to form feedbacks in such a way so that an closed, in terms of consumption, system would have a predetermined disposition of secular equation roots. Below is shown an interrelation of proper numbers and the control vector of final demand, and the general case of control in macroeconomic systems with an incomplete set of fund-creating industries, i.e. when the matrix of capital coefficients is degenerated.

The system (1) reduced to the normal form of Cauchy (state-space representation) looks as follows:

$$\dot{X}(t) = DX(t) + F(t) \tag{2}$$

where $D = B^{-1}(E - A)$, $F(t) = -B^{-1}\Psi(t)$.

This model is open by consumption. Proper values are to be calculated for a closed dynamic system, where final demand vectors are described as consuming products, manufactured in other sectors and producing goods, which they, in their turn, deliver to these sectors. To close the model (2) the final demand vector has to be expressed by other