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MODEL OF STRUCTURAL TRANSFORMATION OF THE ECONOMY OF A MOUNTAIN AGRARIAN REGION

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Abstract

The paper focuses on the problem of structural transformation of the economy of a mountain agrarian region. Technological changes in the production functions of the agricultural sector cause adaptation of the employment structure and, as a consequence, the production structure of the economy of an open region in the medium term. The regional development of small mountain regions with a traditional structure of the economy largely depends on the trajectory for encouraging structural changes. We have presented a model of the impact of technological changes in the agricultural sector on structural changes in the economy of a mountain agrarian region in the medium term, and the classification of technological changes into three types: land-saving, labor-saving and neutral. The proposed model is a two-factor model of the aggregated production function in a small open regional economy, which describes the impact of technological changes on the transformation of the sectoral structure. In the model, the region is a small open agrarian economy with immobile production factors. The conditions of equilibrium in statics are considered and analyzed. It is evidenced that land and labor force as production factors are strong complements, which contribute to the outflow of labor force from the agricultural sector due to labor-saving technological changes in the agricultural sector. It is shown how the proposed model helps make a strategic choice of the program of agricultural extension in a small region with an open economy.

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1. Introduction

Data on the development of mountain regions with an agrarian economy available in scientific literature confirm that the successful economic growth of most of these regions was accompanied by the structural transformation of the socio-economic system (Carter & Zimmerman, 2000; Gollin et al., 2014). As the economy develops and new technologies are introduced, the share of agriculture in employment decreases, and the number of people migrating to cities in search for work in the industrial and service sectors increases (Hornbeck & Naidu, 2014). The migration can be both external and internal, and stimulate the growth of labor productivity in the region and regional economic development (Gollin et al., 2002; Kongsamut et al., 2001; Ngai & Pissarides, 2007). All this show that the identification of forces that are capable of initiating structural transformation is key to understanding of the process of managing the development of a mountain region. In particular, the increased agricultural productivity is an important condition for an agrarian-oriented economy, which ensures economic development and changes in the structure of the economy (Minh, 2009; Samygin, 2017). Paradoxical as it may seem, the increased agricultural productivity in a traditional agrarian region leads in the long term to the decreased proportion in the overall structure of gross output (Acemoglu, 2010). Modern formal models of structural transformation show how productivity growth in agriculture can release labor force or create demand for manufactured goods (Gurtuev et al., 2013; Nunn & Qian, 2011). At the same time, a great number of models consider the impact of agricultural productivity on industrialization in a closed economic system (Kislitsky et al., 2019; Pei et al., 2013), whereas in regions with an open economy, the comparative advantage in the agricultural sector can hamper the growth of other sectors of the economy. (Foster & Rosenzweig, 2008; Hornbeck & Keskin, 2015).

The paper presents a model of the impact of technological changes in the agricultural sector on structural changes in the economy of a mountain agrarian region in the medium term. The model shows that a Hicks-neutral increase in agricultural productivity reduces the size of the industry as the labor force is redistributed in favor of agriculture, as in classic open economy models (Acemoglu & Guerrieri, 2008; Herrendorf et al., 2013). Similar results are obtained for land-saving technologies. In contrast, if land and labor force as production factors are strong complements, labor-saving technological changes in the agricultural sector reduce the demand for labor force and cause the flow of labor into industry. Thus, the model predicts that the impact of agricultural productivity on structural transformation in an open economy of an agrarian region depends on the factor characteristics of the introduced technology, namely, on whether the balance of production factors will shift towards labor saving.

2. Problem Statement

The study presents a model of the impact of technological changes in the agricultural production industry on structural changes in the regional economy in the medium term. At the same time, the main issue is identification and quantification of the relationship between the types of technological innovations and the vector of structural transformations, and the direction of the flow of labor resources.

3. Research Questions

The model shows how an increase in agricultural productivity affects the economic structure of a small open mountain region. At the same time, three types of technological changes are considered: Hicks-neutral, labor-saving and land-saving.

4. Purpose of the Study

The purpose of the study is to develop a mathematical model of the impact of the nature of technological changes in the agricultural sector on the structure of the regional economy in the medium term.

5. Research Methods

The study employed the methods of mathematical modeling, in particular, a model of an equilibrium open market in statics was created.

6. Findings

Consider a simple model describing the impact of the factor of technological changes on structural transformation in an open regional economy. Let the mountain region represents a small open agrarian economy, that is goods can be freely sold in different regions (on the external market), but the production factors are immobile. Consider the simplest case that involves two aggregated sectors of the economy, agriculture and industry, and two production factors, land and labor.

A small open economy is characterized by a number of economic agents, each of which has L units of labor. There are two sectors, industry and agriculture, that produce goods available for trade. Production of industrial goods requires only labor, and the labor productivity in industry is A_m. Thus, the gross industrial output in our model will be $Q_m = A_m L_m$, where L_m is the amount of labor used in the industry. Production in the agricultural sector requires both land and labor, and takes the form of the production function with a constant elasticity of substitution:

$$Q_a = A_N \left[\gamma (A_L L_a)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_T T_a)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{\sigma-1}{\sigma}} \quad (1)$$

where Q_a is the gross agricultural output,

L_a and T_a are the production factors of labor and land, respectively,

A_N is Hicks-neutral technological changes,

A_L is technological changes that lead to a relative decrease in labor use,

A_T is technological changes that lead to a relative decrease in land use,

σ is a positive parameter that indicates the elasticity of substitution between land and labor,

γ is distribution of the shares of production factors, $\gamma \in (0,1)$.

Production function (1) yields the expression for the marginal product of labor:

$$MPL_a = A_N A_L \gamma \left[\gamma + (1-\gamma)\left(\frac{A_T T}{A_L L_a}\right)^{\frac{\sigma-1}{\sigma}} \right]^{\frac{1}{\sigma-1}} \quad (2)$$

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Therefore, neutral and land-saving technological changes increase the marginal product of labor. However, labor-saving technological changes lead to two opposite effects on the marginal product of labor. First, an increase in A_L means that each worker is more productive, as can be seen in the first term in the equation. Second, an increase in A_L leads to a decrease in the amount of land per unit of labor in units of efficiency ($A_T T / A_L L_a$), which, in turn, leads to a decrease in the marginal product of labor. This effect is more obvious when land and labor force are weak substitutes as production factors.

Thus, the relative strengths of these two opposite effects depend on the value of the parameter σ. In particular, **∂MPL_a/∂A_L < 0**, when the substitution elasticity is less than the share of land as a production factor in the gross output. In this case, technological changes significantly reduce labor costs.

Consider an open economic system of a mountain agricultural region trading on the external market, where the relative internal and external prices for agricultural products are represented as $P_a/P_m = (P_a/P_m)^*$. The condition for maximizing profits leads to the fact that the value of the marginal product of labor should balance the wages in both industries. Hence:

$$P_a MPL_a = w = P_m MPL_m \quad (3)$$

Thus, in equilibrium, the marginal product of labor in the agricultural sector is determined by world (external) prices and labor productivity in industry – $MPL_a = (P_a/P_m)^* A_m$. This condition and the condition of the equilibrium state of the land market (**$T_a = T$**) determine the equilibrium distribution of labor and employment in agriculture:

$$L_a^* = \frac{A_T T}{A_L} \left[\frac{\gamma}{1-\gamma} \frac{1-\Gamma^*}{\Gamma^*} \right]^{\frac{\sigma}{\sigma-1}} \quad (4)$$

where $\Gamma^* = \gamma^\sigma \left(\frac{P_m A_m}{P_a A_L A_N} \right)^{1-\sigma}$ is the equilibrium share of labor.

In turn, the equilibrium level of employment in industry, L_m^*, can be obtained from the equilibrium condition on the labor market, $L_m + L_a = L$. Then, when L_m^* and L_a^* are known, the gross output of each industry is found using the production function (1).

Consider the impact of three types of technological changes, namely, Hicks-neutral, labor-saving and land-saving, on employment in both sectors of the regional economy in our model.

Labor-saving technological changes

The impact of labor-saving technological changes on employment in regional agriculture depends on the ratio of the substitution elasticity and the share of land as a factor of production in equilibrium ($\sigma/(1-\Gamma^*)$). If it is less than 1, land and labor in the production function can be considered strong complements. In this case, the following conditions are met:

$$\frac{\partial L_a^*}{\partial A_L} < 0$$

$$(5)$$

$$\frac{\partial L_m^*}{\partial A_L} > 0$$

An increase in A_L triggers labor flaw from agriculture to industry. This can be explained by the fact that if the substitution elasticity between labor and land is less than the share of land as a production factor in the gross output, labor-saving technological changes decrease the marginal product of labor in agriculture. Since in equilibrium the marginal product of labor in agriculture is determined by world

prices and labor productivity in industry, it does not change with increasing A_L. Thus, to increase the marginal product of labor to its equilibrium level, employment in agriculture should decrease.

In the case when land and labor in the production function cannot be considered as strong complements, the following conditions are met:

$$\frac{\partial L_a^*}{\partial A_L} > 0$$

$$\frac{\partial L_m^*}{\partial A_L} < 0$$

(6)

In this case, an increase in A_L causes, in our model, labor flow from industry to agriculture. This is due to the fact that if the elasticity of substitution exceeds the share of land as a production factor in the gross output, labor-saving technological changes increase the marginal product of labor in agriculture.

Land-saving technological changes

$$\frac{\partial L_a^*}{\partial A_T} > 0$$

$$\frac{\partial L_m^*}{\partial A_T} < 0$$

(7)

In the model, an increase in A_T leads to labor flow from industry to agriculture due to an increase in the marginal product of labor in agriculture because of the introduction of land-saving technologies (2).

Hicks-neutral technological changes

$$\frac{\partial L_a^*}{\partial A_N} > 0$$

$$\frac{\partial L_m^*}{\partial A_N} < 0$$

(8)

An increase in A_N also leads to labor flow from industry to agriculture. It should be noted that a Hicks-neutral increase in agricultural productivity also leads to an increase in the marginal product of labor (2).

Consider predictions of the model by examining the simultaneous distribution of two new agricultural technologies, labor-saving and land-saving. As examples, take the technologies of growing genetically modified soybeans and second-crop corn. Note that these are only examples, for different mountain regions, with regard to their climatic conditions, other examples of labor-saving and land-saving technologies may be appropriate (Lagakos & Waugh, 2013; Min et al., 2017). However, the conclusions yielded by the model do not lose their force. In the case of soybeans, the advantage of genetically modified seeds over traditional seeds is that they are resistant to herbicides, which reduces the need for preparatory work. As a result, the technology requires less labor per unit of land to produce the same product. As for corn, the introduction of cultivation technology that allows two harvests per year increases the efficiency of land use. When analyzing real data, the impact of these two types of technological changes on the observed variables in the agricultural and industrial sectors should be quantified and reflection of the patterns predicted by the model should be varified.

7. Conclusion

The proposed model of the impact of technological changes in the agricultural sector on structural changes in the economy of a mountain agrarian region in the medium term can be used to analyze the real data of the consequences of agricultural extension. The model shows that a Hicks-neutral increase in agricultural productivity decreases the size of industry due to the labor force flow to agriculture, as in classic open economy models (Acemoglu & Guerrieri, 2008; Herrendorf et al., 2013). Similar results are obtained for land-saving technologies. In contrast, if land and labor force as production factors are strong complements, labor-saving technological changes in agriculture reduce the demand for labor force and cause the labor flow to industry. Thus, the model predicts that the impact of agricultural productivity on structural transformation in an open economy of an agrarian region depends on the factor characteristics of the introduced technology, namely, on whether the balance of production factors will shift towards labor saving.

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