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The study of industrial structure change and economic growth in China's new economic based on optimal control model

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Abstract

The rapid growth of knowledge-based economy driven by the information technology revolution has had a profound impact on China's economic growth and industrial structure change. This paper re-examines the relationship between China's economic growth and industrial structure change based on the optimal control model. Furthermore, numerical simulations using the three industrial structure change models are carried out by using the parameters suitable for China. The empirical analysis shows that the share of each consumption sector is finally stabilized, and the economic growth rate depends on the technological progress rate of the capital goods sector.

Key words: *economic growth; industrial structural transformation; new economy; optimal control model*

1 Introduction and literature review

The connotation of the industrial structure evolution is violently worldwide today. Not only agriculture and animal husbandry times in which the first industry as the leading industries for a country's economic development basic died, but also the industrial age in which the second industry as the main support for the economic development also drift away. Under the background of new economy in China, industry has grown rapidly by the information technology revolution; especially intellectual economic industry got a rapid growth, which has had a profound impact on economic growth and industrial structure change. So the fixed capital formation is not only in industrial sector. Aiming at these characteristics in China, we re-research on the relationship between economic growth and industrial structure. Firstly, we will review the existing literature, which can be divided into two broad categories from the

perspective of the mechanism of industrial structure change. In the first kind of literature is believed that it is the income effect that causes industrial structure change, and they emphasized on Engel's law mainly from the demand side. This kind of literature also assumed that consumers would reduce consumption of agricultural products, and increase consumption of service products as income rose by a setting non-homothetic preference utility function, which is represented by Kongsamut et al. (2001)[1]. There are also some others, such as Echevareia (1997)[2], Foellmi & Zweimuller (2008)[3], Dennis & Iscan (2009)[4], Boppart (2011)[5] and Li & Gong (2012)[6].

In the second kind of literature, it is believed that it is the price effect that causes industrial structure change. This kind of literature divided economic activities in progressive sector and stagnant sector. Agriculture and industry belongs to progressive industry, while service industry belongs to stagnant industry. So relative price will rise because technological progress in service industry is slower. The labour will flow to the service sector from agricultural and industrial sector, which lead to structural change. Such literature as Baumol (1967)[7], Ngai & Pissarides (2007)[8], Acemoglu & Guerrieri (2008)[9], Caselli & Coleman (2001)[10], Rogerson (2008)[11] and Duarte & Restuccia (2010)[12].

The remainder of this paper is organized as follows: In Section 2, we will introduce the theoretical model of structure change and economic growth. In Section 3, we will give the possibility and characteristics of several kinds of structural changes. In Section 4, we will conclude the paper.

2 The model of the industrial structure change

2.1 The production

We divide the economy into two kinds of sectors. The first kind of sectors is for the production of consumption. The second kind of sectors is for the production of investment. Furthermore, we divide the sector of consumption production into three kinds, including the sector of agricultural consumption production, industrial consumption production, service consumption production. Using labour extensibility technological progress, the models of production functions of capital goods and consumption goods are as follows

$$c_{it} = \left(A_{it} l_{it}\right)^{1-\theta} \left(\varphi_{it} K_t\right)^{\theta},\ i \in \{a, m, s\}, \qquad X_t = \left(A_{xt} l_{xt}\right)^{1-\theta} \left(\varphi_{xt} K_t\right)^{\theta}, \qquad \dot{K}_t = X_t - \delta K_t \tag{1}$$

$$\varphi_{at} + \varphi_{mt} + \varphi_{st} + \varphi_{xt} = 1, \qquad l_{at} + l_{mt} + l_{st} + l_{xt} = 1 \tag{2}$$

where c_{at}, c_{mt}, c_{st} represent the productions of agricultural consumption, industrial consumption, and service consumption respectively. X_t represents the production of investment goods. We normalize the price of sector of investment production to 1. We assume that the relative prices of the three consumption sector to the investment sector are p_{at}, p_{mt}, p_{st}, respectively. Then the profit maximization models for the three consumption sectors and the investment sector of enterprise are as follows, respectively

$$\max_{l_{it},\varphi_{it}} \left\{ p_{it}\left(A_{it}l_{it}\right)^{1-\theta}\left(\varphi_{it}K_t\right)^{\theta} - W_t l_{it} - R_t\varphi_{it}K_t \right\},\ i \in \{a,m,s\} \tag{3}$$

$$\max_{l_{xt},\varphi_{xt}} \left\{ \left(A_{xt}l_{xt}\right)^{1-\theta}\left(\varphi_{xt}K_t\right)^{\theta} - W_t l_{xt} - R_t\varphi_{xt}K_t \right\} \tag{4}$$

where W_t is wage rate, R_t is the rent rate of capital.

2.2 The households

We consider the representative family's consumption preferences and utility function in this section. Following Kongsamut et al. (2001)[1], we define the consumers' composite consumption (recorded as C_t) as follows

$$C_t = \left[\omega_a^{1/\varepsilon}\left(c_{at} - \bar{c}_a\right)^{(\varepsilon-1)/\varepsilon} + \omega_m^{1/\varepsilon} c_{mt}^{(\varepsilon-1)/\varepsilon} + \omega_s^{1/\varepsilon}\left(c_{st} + \bar{c}_s\right)^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)} \tag{5}$$

where $\bar{c}_a, \bar{c}_s > 0$ indicates that the household has non-homothetic preference. $\bar{c}_a$ denotes the consumption of agricultural goods which is used to maintain survival. By this assumption, consumption of agricultural goods will not be lower than $\bar{c}_a$ and consumers can only gain utility from $c_{at} - \bar{c}_a$. $\bar{c}_s$ means that the goods which is self-provided by family members. This is because families' self-provided services can replace the purchasing services and thus forming utility. For example, young couple will save the cost of Yue Sao when their parents help them to take care of the third generation. $\omega_i > 0$ ($i \in \{a,m,s\}$) denotes the consumption weight of the three sectors in long-term trend, which meet $\omega_a + \omega_m + \omega_s = 1$. $\varepsilon > 0$ denotes alternative elasticity of products among sectors. When $\varepsilon > 1$, products between different sectors are substitutes; when $\varepsilon < 1$, products between different sectors are complementary products. The problem of household can be expressed as follows

$$\begin{aligned} &\max_{c_{at},c_{mt},c_{st},K_t} \int_0^{\infty} e^{-\rho t} \ln C_t dt \\ &s.t. \quad \dot{K}_t = A_{xt}^{1-\theta} K_t^{\theta} - p_{at}c_{at} - p_{mt}c_{mt} - p_{st}c_{st} - \delta K_t \end{aligned} \tag{6}$$

where $K_0 > 0$ is given and $\rho > 0$ denotes the discount rate.

2.3 Competitive equilibrium

Using the optimal method, we solve the problem of the firm and the households. Then we can obtain the price of composite consumption as follows

$$P_t = \left[\omega_a \left(p_{at} \right)^{1-\varepsilon} + \omega_m \left(p_{mt} \right)^{1-\varepsilon} + \omega_s \left(p_{st} \right)^{1-\varepsilon} \right]^{1/(1-\varepsilon)} \tag{7}$$

Then we have formula as follows

$$p_{at}c_{at} + p_{mt}c_{mt} + p_{st}c_{st} = P_tC_t + p_{at}\overline{c}_a - p_{st}\overline{c}_s \tag{8}$$

The resource constraint equation can be written as

$$\dot{K}_t = A_{xt}^{\ 1-\theta} K_t^{\theta} - P_tC_t - p_{at}\overline{c}_a + p_{st}\overline{c}_s - \delta K_t \tag{9}$$

In order to analyse the structural change, we split the original problem into the following two sub-problems:

Problem I: Inter-temporal Dynamic Optimization

$$\begin{aligned} &\max_{C_t, K_t} \int_0^{\infty} e^{-\rho t} \ln C_t dt \\ &s.t. \quad \dot{K}_t = A_{xt}^{\ 1-\theta} K_t^{\theta} - P_tC_t - p_{at}\overline{c}_a + p_{st}\overline{c}_s - \delta K_t \end{aligned} \tag{10}$$

That is the household chooses the optimal path of the composite consumption to maximize its lifetime utility under the given condition $K_0 > 0$ and resource constraints.

Problem II: Static optimization problem

$$\begin{aligned} &\max_{c_{at}, c_{mt}, c_{st}} \left[\omega_a^{1/\varepsilon} \left(c_{at} - \overline{c}_a \right)^{(\varepsilon-1)/\varepsilon} + \omega_m^{1/\varepsilon} c_{mt}^{(\varepsilon-1)/\varepsilon} + \omega_s^{1/\varepsilon} \left(c_{st} + \overline{c}_s \right)^{(\varepsilon-1)/\varepsilon} \right]^{\varepsilon/(\varepsilon-1)} \\ &s.t. \quad p_{at}c_{at} + p_{mt}c_{mt} + p_{st}c_{st} = P_tC_t + p_{at}\overline{c}_a - p_{st}\overline{c}_s \end{aligned} \tag{11}$$

To research the changing path of three consumption sectors with the development of economic growth, we will mainly analyse Problem II. We can obtain equations as follows

$$\left(c_{at} - \overline{c}_a \right) / c_{mt} = \left(\omega_a / \omega_m \right) \left(A_{at} / A_{mt} \right)^{(1-\theta)\varepsilon}, \quad \left(c_{st} + \overline{c}_s \right) / c_{mt} = \left(\omega_s / \omega_m \right) \left(A_{st} / A_{mt} \right)^{(1-\theta)\varepsilon} \tag{12}$$

$$P_tC_t / p_{mt}c_{mt} = \left[\left(\omega_a / \omega_m \right) \left(A_{mt} / A_{at} \right)^{(1-\theta)(1-\varepsilon)} + 1 + \omega_s / \omega_m \left(A_{mt} / A_{st} \right)^{(1-\theta)(1-\varepsilon)} \right] \tag{13}$$

We will focus on (12) and (13) in the following analysis. Now, we will discuss the structure changes in several cases.

3 Theoretical analysis of industrial structure change

Assuming that the technological progress rate in each sector is constant, we obtain $\dot{A}_{it} / A_{it} = \gamma_i, (i \in \{a, m, s, x\})$. Then we analyse in several cases when the values of parameters $\omega_a, \omega_m, \omega_s, A_{at}, A_{mt}, A_{st}, \gamma_i, \varepsilon, \overline{c}_a, \overline{c}_s$ change.

Case 1: $\omega_a = \omega_m = \omega_s, A_{at} = A_{mt} = A_{st}, \varepsilon \to \infty, \overline{c}_a = \overline{c}_s = 0$.

In this case, the model degenerates into the growth model of two sectors. The household can choose any proportion of the products of the three sectors, and the utility of the household will not be different. Structural change will not happen in this case.

Case 2: $\varepsilon = 1, \overline{c}_a = \overline{c}_s = 0$.

In this case, $\varepsilon = 1$ means $C_t = c_{at}^{\omega_a} c_{mt}^{\omega_m} c_{st}^{\omega_s}$; the meaning of $\overline{c}_a = \overline{c}_s = 0$ means that there is no non-homothetic preference for household's consumption of the three sectors. Structural change will also not happen in this case.

Case 3 (Income Effect): $\overline{c}_a > 0, \overline{c}_s > 0, \gamma_i = \gamma_j, i, j \in \{a, m, s\}, \varepsilon = 1$.

In this case, $\overline{c}_a > 0, \overline{c}_s > 0$ means that with the increase of incomes, household will reduce the consumption of agricultural products, but increase the consumption of service products; $\gamma_i = \gamma_j, (i, j \in \{a, m, s\})$ means that the technological progress rates of the three consumption sectors are the same (denoting γ_c); $\varepsilon = 1$ means $C_t = \left(c_{at} - \overline{c}_a\right)^{\omega_a} \left(c_{mt}\right)^{\omega_m} \left(c_{st} + \overline{c}_s\right)^{\omega_s}$.

In the following, we will tackle two questions.

Question 1: What is the meaning of the condition required by GBGP in Case 3? What is the initial condition of GBGP?

Question 2: What are the change trends of the share of consumption, value-added and employment in the three sectors?

In analysing of the two questions above, we obtain the conditions of GBGP by theorem 1.

Theorem 1: Assuming that the following conditions hold

$$R - \delta - \rho = \gamma_x, \quad \overline{c}_a / \overline{c}_s = \left(A_{a0} / A_{s0}\right)^{1-\theta}$$

$$K_0 = A_{x0} \left(\theta / (\gamma_x + \delta + \rho)\right)^{1/(1-\theta)}, \quad \overline{c}_s < \omega_s \left(A_{s0} / A_{x0}\right)^{1-\theta} \left[K_0^{\theta} A_{x0}^{1-\theta} - \left(\gamma_x + \delta\right) K_0\right] \tag{14}$$

Then we will have a unique GBGP, on which the growth rate of output depends on the rate of growth of the technological progress rate of the investment sector, while the nominal added value share and employment share of the investment sector remain constants. The nominal consumption share, nominal added value share and employment share of the agricultural sector all remain decreasing. In contrast, those of the industrial sector all remain unchanged and those of the service sectors all remain increasing.

In fact, structural change under this situation is caused by "income effect", which can be explained from the demands of residents. This is the reason for the industrial structure change. Since the reform and open policy in China, the demand factor plays a very important role in a country's industrial structure change. The upgrade of demand structure will lead to the occurrence of industrial structure change.

Case 4 (Price Effect): $\overline{c}_a = \overline{c}_s = 0, \varepsilon \neq 1$.

In this case, $\overline{c}_a = \overline{c}_s = 0$ means that consumers do not have non-homothetic preference. Because people's preference for consumption of agricultural products, industrial products, and service products is different, three kinds of consumptions should be complementary, so we assume $\varepsilon < 1$. According to Brandt & Zhu (2010)[13], we assume $\gamma_a > \gamma_m > \gamma_s$. In this case, we can obtain two conclusions as following:

Result 1: $d\left(l_{at} / l_{mt}\right) / dt < 0$, which means that the ratio of labour share in the agricultural sector to that in the industrial sector is decreasing. In any case, the employment share in the agricultural sector cannot be increasing, nor can it remain the same. Otherwise, the employment share in the industrial sector and the service sector will both be increasing from inequalities $d\left(l_{at} / l_{mt}\right) / dt < 0$ and $d\left(l_{st} / l_{mt}\right) / dt > 0$. So the value of $l_{at} + l_{mt} + l_{st}$ will be increasing. Because $X_t / Y_t = l_{xt}$ is a constant, $l_{at} + l_{mt} + l_{st} = 1 - l_{xt}$ is also a constant. These two conclusions contradict each other. Thus the employment shares in the agricultural sector have to be decreasing in any case.

Result 2: $d\left(l_{st} / l_{mt}\right) / dt > 0$, which means that the ratio of labour share in the service sector to that in the industrial sector is increasing. In any case, the employment share in the service sector cannot be decreasing, nor can it be the same. Otherwise, the employment share in the agricultural sector and the industrial sector will both be decreasing from inequalities $d\left(l_{at} / l_{mt}\right) / dt < 0$ and $d\left(l_{st} / l_{mt}\right) / dt > 0$. So the value of $l_{at} + l_{mt} + l_{st}$ will be decreasing. Because $X_t / Y_t = l_{xt}$ is a constant, $l_{at} + l_{mt} + l_{st} = 1 - l_{xt}$ is also a constant. These two conclusions contradict each other. Thus the employment shares in the service sector have to be increasing in any case.

Summarizing the two results above, we obtain theorem2 as follows.

Theorem 2: Supposing that $\overline{c}_a = \overline{c}_s = 0, \varepsilon < 1, \gamma_a > \gamma_m > \gamma_s$, then there will be a unique GBGP.

On the generalized balanced growth path, the growth rate of output depends on the rate of growth of the technological progress rate of the investment sector, while the nominal added value share and employment share of the investment sector remain constants. The nominal consumption share, the nominal added value share and the employment share of the

agricultural sector all remain decreasing. In contrast, those of service all remain increasing. But those of the industrial sector are uncertain. If they are decreasing, then the rate of decline is slower than those of the agricultural sector. If they are increasing, then the rate of increase is slower than those of the service sector. They may also remain unchanged.

In fact, structural change under this situation is caused by "price effect", which is similar to the analysis in Ngai & Pissarides (2007)[8]. Since the reform and open polity in China, the productivities in the three sectors have been greatly improved. Firstly, agricultural productivity has been greatly improved and modern industry, advanced science and technology and advanced management methods are popularized. Secondly, industrial productivity has also been improved, but many are still in the bottom end of the industrial production chain. Thirdly, as some knowledge-intensive industries, such as electronic information, finance, communications are also weak in China, the improvement of service productivity is limited. This case in China fits the set of $\gamma_a > \gamma_m > \gamma_s$ .So the "price effect" in China is due to the technology progress rates in the three sectors are different.

4 Conclusions

In the new normal stage of our country, the new economy has achieved rapid growth. The share of the software industry's income in capital asset is increasing, so the capital asset in the service sector accounts for an increasing share, which has changed the way of economic growth in China, so as the characteristics of structural change. We divide the economy into two sectors: the investment sector in which capital goods is produced and the consumption sector in which consumption goods is produced. Using the concept of GBGP, we obtain the conclusion that the economic growth is compatible with structural change. We mainly obtain three conclusions. Firstly, the growth rate of the economy depends on the technological progress rate in the investment sector, which means that the key of developing a country's economy is to improve the technological progress rate of the investment sector, such as accelerating innovation and research and development of software industry. Secondly, the trend of change in the structure of material consumption goods is relatively slow for post-industrial countries. Finally, in new normal stage in China, new economy brings new growth model. To adjust structure and promote growth, we should develop new economic industries, such as increase research and development efforts of knowledge industry to start the development engine of industry upgrade.

The possible further research direction is as follows: Firstly, we can promote the model in an open framework in further research. Secondly, we can study the impaction of new economy on China's economic growth empirically in further research.

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