

A Marxian Optimal Growth Model of China: 1981–2005

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1. Introduction

The Communist leadership that came to power in 1949 has launched China on the path of modern economic growth within a socialist framework. After the heavy start period of 30 years for state-lead capital accumulation which is called state-capitalism,¹⁾ the newborn country has stepped into a new era of economic development by claiming to enact the state policy of reform and opening-up in the year of 1978. This year is generally regarded as another new milestone of the history in China's economic growth, because from that time China has progressed to the era of private-capitalism (or market-capitalism), and achieved and maintained amazingly high GDP growth rate in these 30 years, which is seen as a typical successful case and even considered by someone that this miracle of high growth will continue forever. However, from the Marxian understanding, a capitalist era is a long period for accumulating enough capital in order to support consumption at maximum level one day. Therefore, when its ultimate value is reached, the capital labor ratio may reach ultimate equilibrium value, and GDP growth rate will also slump to a low level, as is happening in some developed countries right now. Therefore, historically and materialistically speaking, the downturn of China's economic growth pace is inevitable, and zero-growth will happen in the future, which is exactly the ultimate goal of high economic growth China is experiencing now. The objective of this paper is to identify how long we will experience capitalist era, and how much capital we have to accumulate to meet the level required by the next era of post-capitalism, which is based on "Marxian Optimal Growth Model".

The "Marxian Optimal Growth Model" adopted in this report is formulated by Yamashita & Ohnishi (2002) and extended by Kanae (2008), and is characterized that it simplifies means of production into capital and labor. For the simulation of China's economic growth route based on this model, the capital stock and labor force invested to China's economic activity in the recent 25 years are calculated and introduced to the model. As a result, the production growth paths of two economic parts which are for consumption goods sector and production goods sector will be derived, and the optimal capital labor ratio as well as the time needed to reach the stationary stage in the condition of China will be projected according to the examination of the growth paths.

1) State-capitalist is a period before market-capitalism, when government mainly controls the economic resources and intervene the economic performances.

As the basic model for the precedent study, the “Marxian Optimal Growth Model” formulated and described the understanding of Capitalist system based on the Marxian economic theory. According to the model, labor force is treated as the only ultimate factor input to whole economic production,²⁾ and two parts of consumption goods sector and production goods sector are given. Kanae (2008) augmented the “Marxian Optimal Growth Model” as an “extension model”, where the same as consumption goods sector, two factors of production both labor and capital, are input into production goods sector.

There have been several empirical analyzes of Marxian Optimal Growth Model. Liu (2010) conducted empirical studies for the basic model with panel macro data of Japan, which covered the period from 1975 to 2005, with 47 regions. Tazoe (2010) also executed an analysis on the basic model in the case of Japan. However, he executed the empirical work with standard tools for DSGE models. Roxiangul (2009) did the empirical studies based on the extension model, and added a factor of production of renewable resource by using the data on Japan as well. All of the results obtained by the above studies are consistent with the Marxian optimal growth model. And we will compare the estimation results in section 4.

This paper refers to the “Marxian Optimal Growth Model” and “Extension Model” mentioned above. We will accumulate and analyze data for labor force and capital invested in consumption goods sector and production goods sector respectively in China from 1981 to 2005 to formulate the production functions of the two sectors. Then, optimal capital-labor ratio of China’s economy as well as years required for China’s economy to converge to a stationary stage will be projected through the estimated production functions of two the sectors.

2. The Marxian Optimal Growth Model

2.1 Basic Model

The Marxian optimal growth model set forth by Yamashita & Ohnishi (2002) depicted an optimal path for economic growth of a capitalist society from industrial revolution to the reach of post-capitalism. They constructed the basic model of Marxian optimal growth model, and reinterpreted Marxian theories. In this model, production activities in capitalist society are divided into two parts. The first part is for the consumption goods production, where final goods are produced and could be consumed directly. The second part is production goods sector, where capital goods like machinery are produced to serve for consumption goods production in the first part. Then, labor L of the whole society is accordingly allocated into the two parts at the ratio of $s : 1-s$ ($0 < s \leq 1$). s is the ratio of labor invested to consumption goods sector, and $1-s$ is for production goods sector. So, according to the formulation of Cobb-Douglas type of production function with constant return to scale, consumption goods production would be shown as

$$Y(t) = AK(t)^\alpha [s(t)L]^{1-\alpha}. \quad (2.1)$$

2) It is the main thought of labor theory of value.

For the production goods sector, the left part of labor $(1-s)L$, is considered as the only factor of production without input of capital K .³⁾ Of course, to produce production goods, capital investment like machinery and factory is essential. However, based on the understanding of labor theory of value, machineries and factories used for producing other capitals are ultimately only made by human power. Therefore, labor becomes the only mean of production in production goods sector. Then, assuming that depreciation is not considered here, formula for production goods sector would be

$$\dot{K}(t) = B[1-s(t)]L. \quad (2.2)$$

In this formula, $\dot{K}(t)$ is a time variable, which represents the amount of capital stock change with respect to time. Actually, it is exactly capital investment used for consumption goods production.

In the model, it is assumed that economic resources of the whole society are always allocated rationally as maximization of production efficiency is pursued in the two sectors.⁴⁾ That is the optimal level of K/L , which signals the advent of stationery stage of economy when it is reached. Therefore, optimal allocation of economic resource becomes the mission or the ultimate goal of the whole society, which would be pursued over an infinite period. So, the following formulas⁵⁾ are given to draw the process of optimization of the entire society over time.

$$\max U = \int_0^{\infty} e^{-\rho t} \log Y(t) dt \quad (2.3)$$

$$\text{s.t. } \dot{K}(t) = B[1-s(t)]L \quad (2.4)$$

In the formulas, U stands for total social utility over time; $\log Y$ is for instantaneous utility at time t , and ρ means the rate of time preference.

According to the Marxian optimal growth model, in stationary stage, capital accumulation will completely stop if technology will not change, and all of the labor will be employed for producing consumption goods in the condition that depreciation is disregarded. Thus, $\dot{K}=0$ and $s=1$ is obtained, and optimal capital-labor ratio is as follows.

$$\left(\frac{K}{L}\right)^* = \frac{B\alpha}{(1-\alpha)\rho} \quad (2.5)$$

It is the point where there is no need to produce new capital goods, and where the destination of capitalist society and coming of post-capitalist era which means zero-growth economy is declared. There is no doubt that the present state of China is still far away from the equilibrium point, and China's economy is currently experiencing vigorous capital accumulation.

The detail of basic model has been introduced above excluding the effect of depreciation. In

3) Capital K also will be considered as a factor of production in production goods sector as well as consumption goods sector in extension model, which will be discussed in 2.4.

4) It is assumed that the economy is an optimal production system, which means maximizing the amount of production by the same amount of labor, or minimizing the needed labor to produce the same amount of goods.

5) With regards to optimization over an infinite period, see Barro and Sala-i-Martin (1995)

this part, depletion of production goods will be taken into account at a certain ratio δ . At the stationary equilibrium state, part of labor has to be employed to make production goods in order to maintain the optimal amount of capital, K^* , and to keep the maximum production level of consumption goods. On this purpose, the production function of the production goods sector should be revised as follows.

$$\dot{K}(t) = B[1 - s(t)]L - \delta K \quad (2.6)$$

Although production activities in production goods sector are still going on at equilibrium point to make up the loss caused by depreciation, it should be noted that capital accumulation is in end-stage and labor input for consumption goods production is constant in quantity. Therefore, taking account of $\dot{K}=0$ and $\dot{s}=0$, the optimal level of $\frac{K}{L}$ and s is illustrated as follows.

$$\left(\frac{K}{L}\right)^* = \frac{B\alpha}{\delta + (1-\alpha)\rho} \quad (2.7)$$

$$s^* = 1 - \frac{\delta}{L}K^* = 1 - \frac{\alpha\delta}{\delta + (1-\alpha)\rho} \quad (2.8)$$

Here, $\frac{\delta}{L}K^*$ is just the part of capital depletion which has to be supplemented in production goods sector even at the stationary stage.

2.2 Extension Model of Marxian Optimal Growth Model

In the basic model we have discussed above, one of the most important features is that production goods are produced only by labor force. However, in reality, capital goods used in production of capital goods usually weights more than those used in consumption goods part. Therefore, it is necessary to treat capital goods as an indispensable factor of production as well in production goods sector. Kanae (2008) extended Marxian optimal growth model assuming that capital goods production processes with the collaboration of both labor force and capital goods. The same as the allocation of labor in two sectors, capital goods K are also allocated into the two parts at the ratio of $\theta : 1 - \theta$ ($0 < \theta \leq 1$). The part of θ is the rate of capital invested for consumption goods sector, and the left part of $1 - \theta$ is for production goods sector. The extension model is formulated as follows.

$$Y(t) = A[\theta K]^{\alpha_1}[sL]^{1-\alpha_1} \quad (2.9)$$

$$\dot{K}(t) = B[(1-\theta)K]^{\alpha_2}[(1-s)L]^{1-\alpha_2} - \delta K \quad (2.10)$$

Capital and labor are allocated in consumption goods sector and production goods sector with the ratio of $\theta : 1 - \theta$ and $s : 1 - s$ respectively. And, δ means the depreciation rate of capitals. Further, the optimal capital-labor ratio is obtained as follows.

$$\left(\frac{K}{L}\right)^* = B^{\frac{1}{1-\alpha_1}} \frac{\alpha_1(1-\alpha_2)}{\rho(1-\alpha_1) + \delta(1-\alpha_2)} \left(\frac{\alpha_2}{\rho + \sigma}\right)^{\frac{\alpha_2}{1-\alpha_2}} \quad (2.11)$$

As well, at the equilibrium stationary state, ratio of labor force and capital stock allocated in consumption goods sector and production goods sector is illustrated as follows.

$$L^* : L_c^* : L_k^* = [\rho(1-\alpha_1) + \delta(1-\alpha_2)] : (1-\alpha_1)(\rho + \delta - \alpha_2\delta) : \alpha_1\delta(1-\alpha_2) \quad (2.12)$$

$$K^* : K_c^* : K_k^* = (\rho + \delta) : (\rho + \delta - \alpha_2\delta) : \alpha_2\delta \quad (2.13)$$

This paper intends to present an empirical analysis based on the extension model shown above in the case of China from 1981 to 2005. It is also for the purpose of testifying whether the formulation provided by the model corresponds with the estimation results. Furthermore, the optimal level of $\frac{K}{L}$, ratio of labor and capital stock allocated in each production sector, as well as time required for China's economy to converge to stationary state will be estimated from the empirical analysis.

3. Estimation Model and Data Operation

3.1 Estimation Model

As is shown in the former section, in Marxian optimal growth theory and its extension model, production functions of consumption goods sector and production goods sector are assumed to be of Cobb-Douglas type. The equations can be formulated as follows.

Consumption goods sector :

$$Y(t) = AK_c^{\alpha_1} L_c^{\beta_1} \quad (0 < \alpha_1 < 1, 0 < \beta_1 < 1) \quad (3.1)$$

Production goods sector :

$$G = \dot{K} + \delta K = BK_k^{\alpha_2} L_k^{\beta_2} \quad (0 < \alpha_1 < 1, 0 < \beta_1 < 1) \quad (3.2)$$

The capital stock K_c and labor force L_c input into consumption goods sector shown in the above-mentioned equations indicate the amount of capital stock and labor resource input to the production of consumption goods in direct or indirect ways. Accordingly, K_k and L_k expresses the amount of capital stock and labor force input to produce production goods in direct or indirect ways. Through estimating the production functions provided above, the value of each parameter will be obtained. And whether the derived equations show the constant return of scale will be tested.

The econometric models for estimation are obtained by taking the logarithm of both sides of equation (3.1) and (3.2) in base e , which are shown as follows.

Estimating equation 1 :

$$\ln Y = \ln A + \alpha_1 \ln K_c + \beta_1 \ln L_c + \mu_1 \quad (\mu_1 : \text{error term}) \quad (3.3)$$

Estimating equation 2 :

$$\ln G = \ln B + \alpha_2 \ln K_k + \beta_2 \ln L_k + \mu_2 \quad (\mu_2 : \text{error term}) \quad (3.4)$$

Because one of the main purposes of the empirical analysis is to gain the optimal level of $\frac{Y}{L}$ and $\frac{K}{L}$, the following two equations transferred by equation (3.3) and (3.4) will also be estimated.

Estimating equation 3 :

$$\ln Y - \ln L_c = \ln A + \alpha_1 (\ln K_c - \ln L_c) + (\alpha_1 + \beta_1 - 1) \ln L_c + \mu_3 \quad (3.5)$$

Estimating equation 4:

$$\ln G - \ln L_k = \ln B + \alpha_2(\ln K_k - \ln L_k) + (\alpha_2 + \beta_2 - 1)\ln L_k + \mu_4 \quad (3.6)$$

The estimation of these equations is carried on using the method of ordinary least squares (OLS), and referring to time-series data of China's economy from 1981 to 2005.

3.2 Process for Data Gathering and Operation

The production activity taking place in every industry can be generally classified into two types for its purpose, which is consumption goods production or production goods production. Therefore, to estimate the production functions of the two sectors, the amount of labor force and capital stock input to all industries in China will be calculated first. In the total production of one industry, the part produced for consumption goods can be expressed as $(E-A)^{-1}C$, and the part produced for production goods is expressed as $(E-A)^{-1}I$. Both of them are adjusted to vertical vectors.

Here, E is unit matrix, A is input coefficient matrix, C is the vertical vector for final consumption, and I is the vertical vector for investment.

The capital coefficient k of each industry is adjusted as horizontal vector expressed as follows.

$$k = \left(\frac{K_1}{Y_1}, \dots, \frac{K_n}{Y_n} \right) \quad (3.7)$$

The horizontal vector of labor coefficient l is expressed as

$$l = \left(\frac{L_1}{Y_1}, \dots, \frac{L_n}{Y_n} \right) \quad (3.8)$$

Here, $Y_i (i=1 \dots n)$ shows the production of industry i , K_i is for the capital stock of industry i , and L_i is the amount of labor invested in industry i . Consequently, the amount of capital stock and labor force input in consumption goods sector can be expressed as

$$K_c = k(E-A)^{-1}C \quad (3.9)$$

$$L_c = l(E-A)^{-1}C \quad (3.10)$$

Similarly, the amount of capital stock and labor force input into production goods sector is shown as

$$K_K = k(E-A)^{-1}I \quad (3.11)$$

$$L_K = l(E-A)^{-1}I \quad (3.12)$$

Here, K_c and L_c are capital stock and labor force used in consumption goods production. Accordingly, K_K and L_K express the amount of capital stock and labor force input to produce production goods. What should be done is to estimate every year's value of these four factors in the period from 1981 to 2005 according to the equations provided and then estimate the production functions of the both parts by using the method of ordinary least squares (OLS).

1) Data for input coefficient A

The overall data of input coefficient A is derived out of input-output table provided by the China Statistical Yearbook. However, the input-output table is not renewed every year, but

usually issued in every two or three years. The adoption of input-output table to show the economic relationship amongst China's industries started from the year of 1981, and was renewed in 1987, 1990, 1992, 1995, 1997, 2000, 2002, and 2005 respectively. In view of the discontinuous condition of input-output table's renewal, it becomes impossible to gain the data of input coefficient every year from 1981 to 2005. Therefore, the statistical work of gathering the data of each variable in the purpose of capturing the value about capital stock and labor force is mainly based on the nine year when the input-output table is issued. To solve the problem of the value estimation in the left years, the growth rate of capital stock and labor force is calculated to obtain the value of the year when data resource lacks.

Another problem is caused by the mismatch between the industry items listed in input-output table and the items of labor classification based on the industry. For example, in the input-output table in 2005, the direct input coefficient of manufacturing industry is subdivided as the industry of foodstuff, textile products, and chemical goods and so on. However, classification of the employment information and capital stock is usually not very specific and only the data for the whole manufacturing industry are provided. To use the equations for K and L given in the last section and get the value of them, the number of rows in horizontal vectors of capital coefficient and labor coefficient l should equal the line number in vertical vector of $(E-A)^{-1}C$ and $(E-A)^{-1}K$. Therefore, it is necessary to organize the data in input-output table, and calculate the input coefficient of the whole manufacturing industry. The adjustment is constituted of two parts, the input of other industries into manufacturing and the input of manufacturing into other industries. For the calculation of the former one, the equation can be expressed as follows.

$$\text{input coefficient of industry } i \text{ into manufacturing} = \frac{\sum_{j=1}^n a_{ij}}{Y_m} \quad (3.13)$$

Here, a_{ij} shows the production of industry i , which is input into the production of industry j . And, j is for all specific manufacturing industry categories of foodstuff, textile products, energy refining, chemical industry, material products, metal products, machinery and equipment and others. Y_m is the total production of manufacturing industry.

It is simple to calculate the input coefficient of manufacturing into other industries, and the equation is shown as follows.

$$\text{input coefficient of manufacturing into industry } j = \sum_{i=1}^n a_{ij} \quad (3.14)$$

Here, a_{ij} shows the input coefficient of industry i into industry j . And, i is for all of the nine manufacturing industry items. Because the denominator of coefficient a_{ij} is always the production of industry j , we only need to sum up input coefficients of each category in manufacturing into industry j in order to obtain the contribution ratio of manufacturing to the industry j .

The adjustment is only conducted in the five years of 1995, 1997, 2000, 2002, 2005, because the input-output tables before 1992 contain the input coefficient of the whole secondary industry, and the amount of labor employed in the secondary industry can be found out from the China Statistical Yearbook.

2) Data for consumption C and investment I

In capitalist society, the total output of each industry is ultimately used for two main fields, final consumption C and investment for capital accumulation. The data of final consumption C and investment I are issued every year in the China Statistical Yearbook. The total final consumption expenditures are the sum of three items: rural household consumption, urban household consumption and government consumption expenditures. And the item of investment is generally expressed as gross capital formation in the yearbook, which is the subtotal of gross fixed capital formation and change in inventories. For this empirical study in the case of China, vertical vectors of final consumption C and investment I are formed on the basis of the data in the year of 1981, 1987, 1990, 1992, 1995, 1997, 2000, 2002, and 2005. In addition, the total consumption and investment of manufacturing is calculated and listed in the two vectors by summing up the value of each specific manufacturing industry.

3) The amount of labor input

When analyzing the causes of economic growth, the input of factor of production in one period should be treated not only as the quantity of the factor, but also as the quality or the production efficiency of the factor. For the production functions of Cobb-Douglas type adopted in this research, L refers to the amount of labor forces input in reality, which is the result of the number of employees multiplied by average working hours. This definition is also consistent with the labor theory of value. In general, level of income relates with the production efficiency of labor and working hour closely, and reasonably reflects the quantity change of labor input. However, the relevant data of the income level and labor input of China's society is still incomplete. Therefore, in this paper, the number of employees in each industry is adopted as the data of labor input.

According to the China Statistical Yearbook, the data of employment by industry is issued every year before 2002. And for the year of 2005, the data is derived from the official website of China's economic census by the source of National Bureau of Statistics of China.⁶⁾ The horizontal vector of labor input L is categorized as ten items, which are agriculture, mining and quarrying, manufacturing, production and supply of energy, construction, transport and telecommunications, trade and catering services, real estate and leasing & business services, finance and insurance as well as other services.

4) Data on production Y

The data of total output in each industry can be derived from the China Statistical Yearbook directly. And the output data in each year are calculated at producers' prices of 1991.

5) Capital stock data

Capital stock is considered as one of the essential factors of production which can make the

6) http://www.stats.gov.cn/zgjipc/cgfb/t20051206_402294807.htm

economic production expand continuously and increase the wealth of the whole society. As a variable of stock, capital stock shows the quantity of capital accumulation generated by the previous production activities. In general, capital stock is defined as total amount of capitals owned by all of the economic entities, including tangible and intangible capital goods possessed by individuals, enterprises and the government. However, as the object of statistical estimation, it is usually regarded as the total value of fixed capitals, which is exactly the meaning of K in production functions of Cobb-Douglas type. Unlike the condition of Japan, the data of capital stock in China are not contained in any statistical reports and should be estimated by referring to year-books of industries as well as other documents and researches about this issue.

In this paper, the estimation of capital stock K in each industry is mainly based on the documents of economic yearbooks of industries and yearbook on investment in fixed assets of China, as well as Teng (1999). This paper estimated each year's capital stock value in agriculture, and the tertiary industry from 1981 to 1997, which is partly quoted in this research. Details about how the estimation is conducted in Teng (1999) will be described below.

According to Teng's paper, the capital stock in agriculture is derived from the released data of government, and is estimated by classifying it into two parts – fixed capital stock for agricultural production in farm families as well as state-owned farms. The data of capital stock owned by farm families are obtained from the documents of National Bureau of Statistics, and details about capital stock of state-owned farms are provided by Ministry of Finance. The following is the estimation equation of agricultural capital stock used in Teng's paper.

$$K_a = [k_a - (k_i + k_t)] \times N_f + K_g \quad (3.15)$$

$$N_f = N_a \times 0.9 \quad (3.16)$$

Here, K_a is the gross value of capital stock in agriculture, k_a is the average of fixed capital owned by one farm household; k_i means machinery for industrial production and k_t is machinery for transport. N_f is the total number of farm households in China which occupies 90 percent of rural households N_a .⁷⁾ And K_g indicates the quantity of capital stock of state-owned farms.

Since the estimation of Teng covers every year from 1985 to 1997, the estimation results of 1987, 1990, 1992, 1995, and 1997 are used in my research. Data for 1981 are estimated based on the average growth rate from 1985 to 1990. For the data after the year of 1997, benchmark year method is used to calculate the value of capital stock K in corresponding years. The equation is shown as follows.

$$K_t = (1 - \delta)K_{t-1} + I_t \quad (3.17)$$

Here, δ is the rate of depreciation which differs among industries. It can be derived from the Economic Yearbook on the base of industries. The average depreciation rate of agriculture in the 25 years is calculated and substituted into the equation as 0.025. I_t and K_t mean the formation of new fixed capitals and the value of capital stock in the year of t respectively. The data of I_t after 1997 are derived out of yearbooks on investment in fixed assets of China as well as the economic

7) The rate of 0.9 is derived by national agricultural census in 1996

yearbook, where the amount of fixed capital investment in agriculture every year from 1997 to 2005 is issued. In particular, the data of fixed capital investment in 1999, 2000 and 2001 are extracted from the website named China's statistical data, an official website belonging to the Bureau of Statistics of China I_t .⁸⁾ And then, all the estimation data of capital stock are calculated at the price for fixed assets investment of 1991 by dividing the deflator of $\frac{P_t}{P_{91}}$.

The results of capital stock value in the tertiary industry from 1981 to 1995 estimated in Teng's paper are also adopted in my research. Therefore, it's necessary to explain the process and contents of estimation in Teng's study. As shown in the equation of 3.17, benchmark year method is applied in Teng's research by setting the capital stock value of 1981 as the benchmark, and estimating the value of the following years based on the benchmark. To obtain the benchmark value, the following calculation is conducted by the author.

$$K_{the\ tertiary\ industry} = I_{the\ tertiary\ industry} \times \frac{K_{state\ owned\ company}}{I_{state\ owned\ company}} \quad (3.18)$$

In the equation of 3.18, $K_{the\ tertiary\ industry}$ refers to the estimation value of capital stock in the tertiary industry in 1981; $I_{the\ tertiary\ industry}$ is the amount of fixed assets investment in the tertiary industry in 1981, and $\frac{K_{state\ owned\ company}}{I_{state\ owned\ company}}$ is the ratio between capital stock and investment in state owned companies, which is calculated according to the time series data of fixed capital stock and fixed asset investment in state owned companies. It is assumed here that this ratio sampled by the state owned companies can be applied as one of the whole industry, because the data for private enterprises are not available in official documents. However, bias is detected when comparing the estimation results with the research results obtained from the census of the tertiary industry executed in 1991 and 1992. So the author adjusted the estimation results to make it accord with the census research results. The adjustment equations are shown as follows.

Adjustment equation for estimation results from 1981 to 1991

$$K_t = \left[\frac{K_{91} - K_{81}}{k_{91} - K_{81}} \times (k_t - K_{81}) \right] + K_{81} \quad (t=82, \dots, 91) \quad (3.19)$$

Adjustment equation for estimation results from 1992 to 1997

$$K_t = \left[\frac{K_{92} - K_{81}}{k_{92} - K_{81}} \times (k_t - K_{81}) \right] + K_{81} \quad (t=93, \dots, 97) \quad (3.20)$$

Here, K_t is the adjusted capital stock value of the tertiary industry in year t ; k_t is the estimated value of capital stock in the tertiary industry in year t ; K_{91} and K_{92} are the census data of the tertiary industry in 1991 and 1992, and K_{81} is the benchmark value of the tertiary industry. The capital stock value at the price of 1990 of each sector in the tertiary industry are estimated by the process described above in Teng's paper, and the results of 1981, 1987, 1990, 1992, 1995 are adopted in my research, by transferring them to the value at the price of 1991.

Just the same as how capital stock after 1997 is estimated in agriculture mentioned above, in

8) <http://www.china.com.cn/ch-company/web1.htm>

order to obtain the capital stock of the tertiary industry in 1997, 2000, 2002, and 2005, data of I_t in every year are picked out of the yearbooks on investment in fixed assets of China, the economic yearbook and the website of China's statistical data, and are then transferred into figures at the price for fixed assets investment of 1991. The value of depreciation rate δ in each part of the tertiary industry adopted in equation 3.17 is calculated by averaging the rate in the 25 years. Obviously, the depreciation rate differs among the tertiary departments, which is 0.035 in trades and hotel services ; 0.05 in banking and insurance, and up to 0.2 in real estate and leasing services.

Information about fixed asset investments and capital stock value of manufacturing and construction industry in every year is usually issued in China Industrial Economy Statistical Yearbook and China Construction Statistical Yearbook. In most years, data of total fixed capital stock in the two industries are available in yearbooks, and are transferred to the figures at the price of 1991. And, in the occasion when capital stock value is not contained in the yearbook, calculation is conducted according to equation 3.17 to obtain the capital stock of the two sectors since data of fixed assets investment can be derived out of the yearbooks. The depreciation rate δ adopted in the calculation is still the average value of the manufacturing and construction industry in the 25 years, which are 0.046 and 0.05 respectively.

6) Estimation of the other 16 years

The part described above has shown the process of obtaining the amount of labor and capital stock input into the consumption sector and the production sector, which are sampled in the nine years of 1981, 1987, 1990, 1992, 1995, 1997, 2000, 2002, and 2005, because input-output table is renewed in these years. The amount of invested labor force and capital stock in the two production sectors in the other 16 years are estimated by multiplying preceding year's figure and the geometric mean of growth rate.

4. Estimation Results and Evaluation

The process and details of data gathering and operation have been introduced in the previous section. In this part, we will estimate the equations of the Marxian optimal growth model in the two sectors and then calculate the stable path to the optimal capital-labor ratio based on the econometric model. Furthermore, we will predict when China will end its capitalist era, and step into the post-capitalist era.

The method of OLS is adopted to estimate the production functions of the two sectors, which are shown in equations 3.3 and 3.4. The results of the estimation are as follows.

Here, coefficient of $\ln(L_c)$ is statistically significant at the 10% level ; coefficient of $\ln(L_k)$ is statistically insignificant at the 10% level due to data limitation. However, in this study we take more account of the magnitude of the variable to obtain the optimal capital-labor ratio. Therefore, we will use the value in the following calculation. According to the estimation results, the sum of

Table 1

Estimation equation 1		Estimation equation 2	
Variable	Estimation value	Variable	Estimation value
constant	2.12 (0.80)	constant	1.55 (0.92)
$\ln(L_c)$	0.27 (1.85)	$\ln(L_k)$	0.18 (1.35)
$\ln(K_c)$	0.72(34.31)	$\ln(K_k)$	0.81(19.08)
$R^2=0.987$		$R^2=0.985$	
Observation number : 25		Observation number : 25	
Durbin-Watson ratio : 1.09		Durbin-Watson ratio : 1.33	

Figures in the brackets are t-values.

coefficients of $\ln(L)$ and $\ln(K)$ are both nearly 0.99. This proves that the production functions estimated of both two production sectors are homogeneous functions and are in constant return of scale. So it can be considered that the results do accord with the Marxian optimal growth model. As shown in table 1, the determination coefficient of R-squared is also at a level near to 1, which means that the estimated linear regression equations fit with the related data well. The estimated linear regression equations of consumption goods sector and production goods sector are shown as follows.

$$\ln Y = 2.12 + 0.27 \ln L_c + 0.72 \ln K_c \quad (4.1)$$

$$\ln G = 1.55 + 0.18 \ln L_k + 0.81 \ln K_k \quad (4.2)$$

Equation 3.5 and 3.6 indicating the level of $\frac{Y}{L}$ and $\frac{K}{L}$ are estimated by regression analysis as well. And the results are as follows.

$$\begin{aligned} \ln Y - \ln L_c &= 2.12 + 0.72(\ln K_c - \ln L_c) + (0.72 + 0.27 - 1)\ln L_c \\ &\cong \ln 2.12 + 0.72(\ln K_c - \ln L_c) \end{aligned} \quad (4.3)$$

$$\begin{aligned} \ln G - \ln L_k &= 1.55 + 0.81(\ln K_k - \ln L_k) + (0.81 + 0.18 - 1)\ln L_k \\ &\cong \ln 1.55 + 0.81(\ln K_k - \ln L_k) \end{aligned} \quad (4.4)$$

Because Liu (2010), Tazoe (2010) and Roxiangul (2009) also conducted similar empirical analysis using the data of Japan, we will briefly compare with the estimation results of these studies. Liu (2010) used panel data of the 47 regions of Japan, and estimated the basic model with Three-Stage-Least Squares method. The results are shown as follows.

$$\text{Consumption goods sector : } Y = 30.9 L_c^{0.3} K^{0.46} \quad (4.5)$$

$$\text{Production goods sector : } G = 1.39 \times 10^{-5} L_k^{2.22} \quad (4.6)$$

Since all estimated parameters of her research are significant at the 1% level, it can be confirmed that the basic model accords with the real condition of Japan's economy. Further, we can see diminishing returns to scale in consumption goods sector.

Tazoe (2010) used Bayesian methods to empirically analyze the basic model by estimating it on quarterly data on Japan, which are seasonal consumption data from 1992 to 2009. He obtained

the results as $\alpha=0.42$, $A=4.2$ and $G=21.93L_K$. Parameter α here is quite smaller than that in China. Tazoe (2010) also argued that Japan can be assumed to have already reached stationary equilibrium state according to the Marxian optimal growth model.

Roxiangul (2009) added renewable resources as one factor of production, and estimate the extension model in three sectors of consumption goods sector, production goods sector and natural resource production sector by using time-series data on Japan from 1975 to 2005. The estimation results are shown as follows.

$$\text{Consumption goods sector : } \ln Y = 3.51 + 0.37 \ln K_c + 0.08 R_c + 0.52 L_c \quad (4.7)$$

$$\text{Production goods sector : } \ln G - \ln L_k = 5.42 + 0.39(\ln K_k - \ln L_k) \quad (4.8)$$

$$\text{Resource production sector : } \ln R - \ln L_r = -1.03 + 0.77(\ln R - \ln L_r) \quad (4.9)$$

Here, R is resource stock, R_c is resource input in consumption goods sector, and L_r is labor input in resource production sector. The results support the extension model well, and confirmed that resource input makes sense in production activities as well.

Then, we will calculate the optimal capital-labor ratio according to equation 2.11. Besides the estimated parameters α , β and the value of time preference ρ as well as depreciation rate δ should be set first. To get the value of δ , the average of every year's capital depreciation rate is calculated according to the Statistical Yearbook as approximately 0.075. And we set the value of ρ as 0.2. As a result, the optimal capital-labor ratio is calculated as 49335 RMB per capita. Since this ratio in 2005 is only 22757 RMB for one person, we can identify that it is at approximately 46% level of the optimal ratio in 2005. We can see that China's economy reached almost half of the distance towards the communist society in 2005. Ohnishi (1998) conducted a similar research on Japan, South Korea, Taiwan, Philippine, and Indonesia by comparing capital coefficient in 1994 with the estimated equilibrium value of it (see Table 3). It suggests that Japan's economy has reached a steady state in 1994, since the measured coefficient exceeds the equilibrium value. In contrast, other East Asian countries and regions only reached less than half of the equilibrium state. Comparatively, in our research with more precise data and methodology, China's economic growth lagged backward as it only walked 46% of the marathon in 2005.

Further, according to equation 2.12 and 2.13 provided in section 2.4, we can also obtain the ratio of allocation of labor force and capital stock in the two production sectors when China's economy

Table 3

Countries and Regions	Where the economy were in 1994 (%)
Japan	124
South Korea	36
Taiwan	21
Philippine	39
Indonesia	51

Source : Ohnishi (1998), pp. 10

has reached stationary state. The results are shown as follows.

$$L^* : L_c^* : L_k^* = 1 : 0.85 : 0.15 \text{ and } K^* : K_c^* : K_k^* = 1 : 0.78 : 0.22$$

We can learn from the result that at the equilibrium point, up to 85% of labor and 78% of capital stock will be invested to produce consumption goods, yet merely 15% of labor and 22% of capital stock will contribute to producing product goods and to making up the depreciation of capital stock. Compared with the ultimate condition, in 2005 almost 56% of labor and 60% of capital stock are invested in consumption goods sector, while percentage of labor and capital stock in product goods sector reached 44% and 40% respectively. Still, capital accumulation is progressing in full swing in China currently.

Figure 5 illustrates the trend of capital-labor ratio's change in each production sector from 1981 to 2005. We can see that capital deepening is progressing in both sectors, and capital intensity ratio remains higher in production goods sector than that in consumption goods sector before 2003. During the entire decade of 1990s, capital was deepening rapidly in both sectors, which confirms the amazing economic growth in China in the last decade of the 20th century. However, after the spot of 2001, capital-labor ratio in production goods sector started to slump gradually, and is exceeded by consumption goods sector in 2003, which is called capital reversal. The fact accords with the expectations of the Marxian optimal growth model saying that the speed of capital accumulation will slow down and reach a low level to remain the optimal volume of capital goods at the equilibrium stationary point.

Further, we can see that in these 25 years, capital-labor ratio climbed from 3104 in 1981 to 22757 in 2005, and kept increasing in average amount of 786 annually according to figure 6. As we have expected that the optimal capital-labor ratio is up to 49335, assuming that China will keep the same speed before now, we can roughly estimate that it needs another 34 years to reach the optimal value. Therefore, it can be imagined that in this trend China's economy may reach the

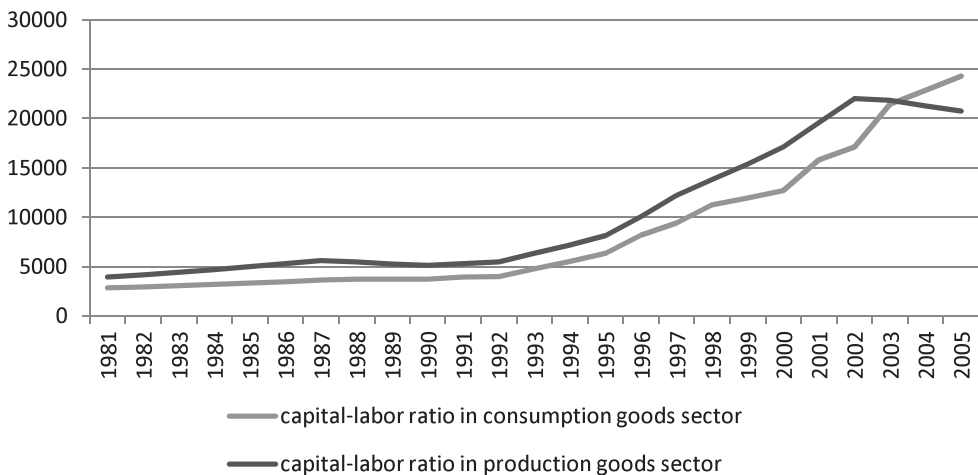


Figure 5

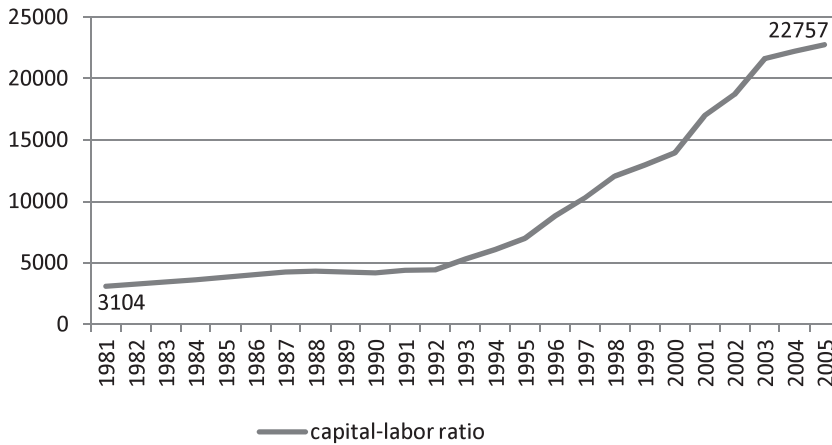


Figure 6

stationary state around the year of 2040, if the growing path is linear. Taking the influence of decrease in investment efficiency into consideration, more time may be required until economic growth rate tends to be almost zero, and the coming of post-capitalist era to be declared.

5. Conclusion

This paper conducted an empirical study of economic growth path in China from 1981 to 2005 in the basis on Marxian optimal growth model and its extension model. It aimed to obtain the production functions of the two production sectors, consumption goods sector and product goods sector by making regression analysis of OLS method, and testified whether the estimated production functions do accord with the basic model and the theory.

Moreover, this paper illustrated the destination of the economic development in China quantitatively by estimating the ultimate value of capital-labor ratio, which is 49335 RMB for one person at optimal level, and provided the allocation ratio of labor force and capital stock in each production sector. Furthermore, it is cleared that China will continue its economic growth for decades since only 46% of the optimal capital-labor ratio has been achieved at the point of 2005, and still huge amount of economic resource should be invested in capital goods production to meet the expanding needs of consumption products. Also, we calculated the allocation ratio of labor force and capital stock in the two sectors at stationary state, which is almost 85% of labor and 78% of capital for consumption products as opposed to 15% of labor and 22% of capital for product goods production.

Finally, we predicted that almost another 35 years are required to reach the stationary state according to the decreasing of capital accumulation rate. We do believe that China will still experience a long time to achieve the communist society, and may face a zero-growth in 2040s just like what other developed countries are experiencing now.

However, due to data limitation, the estimation value of β_2 and the coefficient of L_k are not

shown significant at the 10% level. We also leave an issue of estimating the economic growth path from 1949 to notice the economic conditions in state-capitalist period of China. It will be a further subject of our future studies.

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