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Bangxi Li
Graduate School of Economics
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1-6-1, Nishiwaseda, Shinjuku-ku, Tokyo

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Estimation of Marginal Fixed Capital Coefficient and Wage-Profit Curves à la von Neumann-Leontief: A Case Study of China's Economy 1987-2000 *

Bangxi Li †

Abstract

This paper estimates marginal fixed capital coefficient of China's economy using Sraffa-Fujimori method, and calculates the wage-profit curves in a von Neumann-Leontief model. Main results are: from the 1980s through the 2000s, (i) the short-run and long-run maximum (potential) growth rate tends to decrease; (ii) the maximum (real) wage rate tends to increase; (iii) the marginal capital-output ratio has increased.

Keywords: Marginal Fixed Capital Coefficient, Wage-Profit Curve, von Neumann-Leontief Model

JEL Classifications: B51, C63, E11

1 Introduction

In this paper, several theoretical parameters that are considered important in linear economic theory are calculated using the available data on China's gross investment of fixed capital and its published input-output table at the current stage.

First, China's fixed capital input coefficient (marginal fixed capital coefficient) is estimated from its gross investment of fixed capital data for 1987-2000. On the basis of the standard system of Sraffa (1960), Fujimori (1992) developed a novel method to estimate the Japanese fixed capital coefficient by using the country's gross investment of fixed capital data. This method (called the Sraffa-Fujimori method) is applied to China's economy in an analytic framework. [1]

Second, a basic framework of the von Neumann-Leontief model is clarified. We describe the Chinese economy's wage-profit curves in a von Neumann-Leontief economy, making use of an intermediate input coefficient calculated from the input-output table and fixed capital coefficient estimated using the Sraffa-Fujimori method. Furthermore, we clarify the short- and long-run features of China's economy from 1987 until 2000 by using the short- and long-run wage-profit curves.

2 Estimation of the fixed capital coefficient using the Sraffa-Fujimori method

2.1 Basic framework

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†Graduate School of Economics, WASEDA University, Email: bangxi@y.fuji.waseda.jp

[1] For the calculation of some theoretical parameters in China where fixed capital is not permitted, refer to Li (2008).

Okishio and Nakatani (1975) contracted a joint production system à la Marx-Sraffa with aged fixed capital for a Leontief production system that consisted of only the following brand new goods.

$$p = pM(r) \tag{1}$$
$$M(r) = (\widehat{\psi}(r) + rI)K + (1+r)(A+FL) \tag{2}$$

However, p, A, K, F, L and r represent the production price vector of only brand new goods, input coefficient matrix, fixed capital input coefficient matrix, bundle of wage goods, labor input vector, and uniform profit rate, respectively. $\widehat{\psi}(r)$ is a diagonal matrix that arranged the depreciation rate $\psi_i(r)$ in the diagonal element. Assuming that the durability of fixed capital goods i is τ_i, the depreciation rate $\psi_i(r)$ can be defined as (3).

$$\psi_i(r) = \frac{1}{\sum_{h=0}^{\tau_i - 1}(1+r)^h} \tag{3}$$

Okishio-Nakatani also showed the necessary and sufficient condition for Marx's fundamental theorem in a system that contracted for only brand new goods to be held. [2]

If non-productive consumption is disregarded, a Marx-Sraffa activity level system can be similarly contracted for a Leontief output system of only brand new goods. The equilibrium output system corresponding to an equilibrium production price system (1) is set to (4). [3]

$$q = M(g)q \tag{4}$$

However, q and g are an output vector of only brand new goods and the uniform growth rate, respectively, and $g = r$.

From the Perron-Frobenius theorem,

$$\lambda_{M(g)} = \lambda_{M(r)} = 1$$

is clear.

Now, K does not hold the data we actually require. Only the data of the gross investment matrix can be used for fixed capital data out of the actual input-output data. Therefore, the following paragraph shows how the fixed capital input coefficient matrix K in the above-mentioned theoretical model is estimated from the gross investment data of fixed capital.

2.2 Method of estimating a marginal fixed capital coefficient

Assume that a profit rate change does not affect macro factors, such as exports and imports, and that a demand base is considered.

The intermediate input X_{ij}, final demand Y_i, and total output X_i of an input-output table fulfill the following relations.

$$X_i = \sum_{j=1}^{n} X_{ij} + Y_i$$

[2] For details, see Okishio and Nakatani (1975).

[3] For a detailed discussion of the Marx-Sraffa model, which includes fixed capital, see Fujimori (1982), Schefold (1989, Part II), Kurz and Salvadori (1995, Chap. 7).

The input coefficient matrix $A = (a_{ij})$ is called for as

$$a_{ij} = \frac{X_{ij}}{X_j}.$$

Here, let x be the output, I be the investment, and C be the consumption, then

$$x = Ax + I + C \tag{5}$$

will be obtained from the input-output table.

Hereafter, we try to find the growth rate of Sraffa's standard system that lurks in the actual economy. It is assumed that the consumption C is equally assigned to investment I in a final-demand item.

Investment I is the sum total of inventory investment and the gross investment of fixed capital.

Since inventory investment can be regarded as the accumulation of nondurable goods, it is set to gAx with a growth rate g.

On the other hand, since the gross investment of fixed capital is divided into net investment and depreciation (replacement investment), the amount of net investment is gKx and the depreciated part is set to $\widehat{\psi}(g)Kx$. Since K is not calculated directly, we calculate it from a marginal angle.

Let ΔK be the net investment matrix, and ΔX, the incremental vector of output. The marginal capital coefficient k^*_{ij} at this point will be set to (6).

$$k^*_{ij} = \frac{\Delta K_{ij}}{\Delta X_j} \tag{6}$$

Here, it is assumed that there is no large technical progress. We can also assume that $k_{ij} = k^*_{ij}$. Hereafter, k^*_{ij} will be used instead of the fixed capital input coefficient k_{ij}. Further, we can consider the increment output as $\Delta X = gX$.

Since the ratio γ_i of the net investment to gross investment can be defined as follows,

$$\gamma_i = 1 - \frac{1}{(1+g)^{\tau_i}} \tag{7}$$

we can consider the net investment matrix as $\widehat{\gamma}S$. However, S is the gross investment matrix of fixed capital, and $\widehat{\gamma}$ is the diagonal matrix that arranged γ_i in the diagonal element. [4]

From this, we set the marginal capital coefficient k^*_{ij} to (8).

$$k^*_{ij} = \frac{\gamma_i S_{ij}}{gX_j} \tag{8}$$

In this calculation, k^*_{ij} is dependent on the uniform growth rate g.

Equation (5) is transposed to (9) as $K^*(g) = (k^*_{ij})$.

$$x = M(g)x \tag{9}$$
$$M(g) = (\widehat{\psi}(g) + gI)K^*(g) + (1+g)A \tag{10}$$

If $\lambda_{M(g)} = 1$, g at that point will be equal to the maximum growth rate g^*.

The computational procedure of g^* is shown below.

[4] It should be noted here that $g(g) = g(r)$. In an economy that disregards non-productive consumption, the uniform profit rate r and uniform growth rate g are in agreement. For details, see Fujimori (1982).

(1) A suitably small initial value $g_0 > 0$ is taken. This requires that the Perron-Frobenius root $\lambda_{M(g)}$ of $M(g)$ in (10) be in order.

(2) Then, we check the following. From $\frac{d}{dg}M(g) > O$, an increase in g would make $M(g)$ large, since $M(g)$ is an increasing function of g. Therefore, from the Perron-Frobenius theorem, since

$$g_t < g_{t+1} \Leftrightarrow M(g_t) < M(g_{t+1}) \Leftrightarrow \lambda_{M(g_t)} < \lambda_{M(g_{t+1})},$$

λ also becomes an increasing function of g.

Let $g_{max} = \frac{1}{\lambda_A} - 1$. From $\mid g_t \mid < g_{max}$, g_t is bounded. [5]

Now, if $\lambda_{M(g)} < 1$, the value of g will increase, and if $\lambda_{M(g)} > 1$, the value of g will decrease.

A progression $\{g_0, g_1, g_2, \cdots\}$ is made as

$$g_{t+1} = \delta(g_t) = g_t + \beta(1 - \lambda_{M(g_t)})$$

($\beta > 0$ represents arbitrary constants). Since Marx's fundamental theorem is assumed, it is certain that $g > 0$.

If it is taken that gt is near 0, the following g_{t+1} will appear on a 45° line because of (11).

$$\frac{dg_{t+1}}{dg_t} = 1 - \beta\frac{d}{dg_t}\lambda_{M(g_t)} < 1 \tag{11}$$

$\delta(g_t)$ will cross the 45° line from the top to the bottom.

The relationship between g_{t+1} and g_t can be expressed as in Fig. 1. $g_{t+1} = g_t = g^*$ is called for when we set $1 - \lambda_{M(g_t)} = 0$. $g_{t+1} = \delta(g_t)$ has a fixed point $g_{t+1} = g_t = g^*$. This fixed point is stable by (11). This fixed point can be found by the regula falsi method of numerical computation. [6]

(3) If g^* is fixed, a marginal fixed capital coefficient matrix can be constructed as follows:

$$K^* = \left(k^*_{ij}(g^*)\right) \tag{12}$$

3 Wage-profit curves à la von Neumann-Leontief

3.1 Basic concept

In the normal production process, many factors are used, such as raw material and fixed capital with various terms of durability and age. Brand new fixed capital and aged fixed capital are considered as distinctly different items. In a von Neumann system, the equilibrium problem of such an economy can be described as follows: [7]

$$\max\{pF \mid \frac{1}{1+r}pB \leq pA + L,\ p \geq \mathbf{0}\} \tag{13}$$

Here, A, B, F, L, r, and p represent the input matrix, output matrix, bundle of wage goods, labor input vector, uniform profit rate, and production price vector, respectively.

[5]For details, see Nikaido (1960, Chap.2).

[6]See Takahashi (1996) for details of the regula falsi method.

[7]See von Neumann (1945/46) for details of original von Neumann Model.

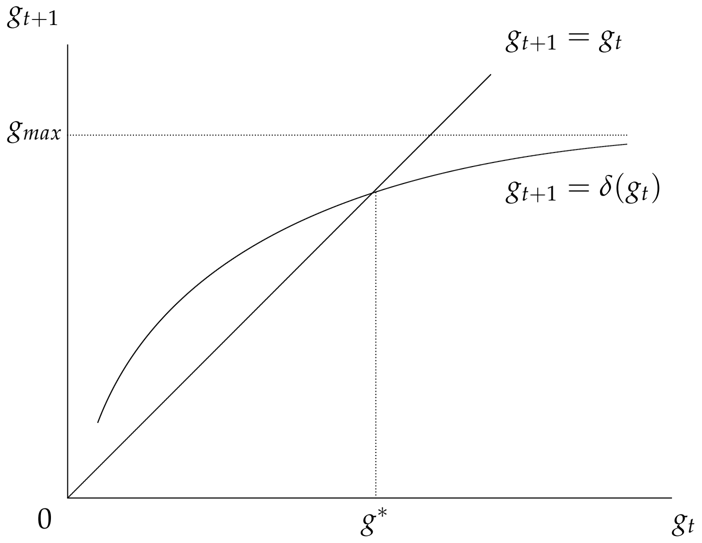

Figure 1: The relationship between g_{t+1} and g_t

We consider this a linear programming problem where the nominal wage rate $w = pF$ is maximized. [8]

Let x be the activity level; the dual problem of (13) is expressed as follows, assuming a uniform growth rate $g = r$:

$$\min\{Lx \mid \frac{1}{1+r}Bx \geq Ax + F,\ x \geq \mathbf{0}\} \tag{14}$$

This dual problem minimizes the labor input in an economy.

Assuming that the efficiency of fixed capital goods is invariable despite difference in age, for this kind of joint production system in a von Neumann economy, we can reduce it to a Leontief system, consisting of only brand new goods and not including aged fixed capital goods at all. As a matter of course, the durability of fixed capital considered in this case is physical durability and is given exogenously. When the system is reduced from a von Neumann economy to a Leontief economy, we can call it a von Neumann-Leontief economy.

Therefore, in a von Neumann-Leontief-type economy, the standard maximum problem (13) is expressed as follows.

$$\max\{pF \mid \frac{1}{1+r}p \leq pA + L + p\left(\frac{r}{1+r}I + \frac{1}{1+r}\widehat{\psi}(r)\right)K,\ p \geq \mathbf{0}_m\} \tag{15}$$

However, in the case of (15), which is expressed as a linear programming problem with m sectors and m goods, A is an (intermediate) input matrix of $m \times m$, F is a bundle of wage goods of $m \times 1$, L is a labor input vector of $1 \times m$, K is a fixed capital input matrix of $m \times m$, τ_i is the durability of fixed capital i, and $\widehat{\psi}$ is a diagonal matrix with a diagonal element of depreciation rate ψ_i of fixed capital i.

The relationship between profit and (real) wage can be expressed as that between profit rate and the number of units in a bundle of wage goods. Therefore, the wage-profit curves should be expressed as $(\frac{1}{pF}, r)$.

[8]See Fujimoto (1975).

Similarly, in order to include fixed capital, the dual problem of linear programming problem (15) is expressed as follows, assuming $g = r$ on a capitalist non-consumption premise:

$$\min\{Lq \mid \frac{1}{1+r}q \geq Aq + F + \left(\frac{r}{1+r}I + \frac{1}{1+r}\widehat{\varphi}(r)\right)Kq,\, q \geq \mathbf{0}^m\} \tag{16}$$

Here, q is the output quantity.

A linear programming problem of this kind should be considered from both short- and long-run perspectives. While, in the long run, the replacement and the net investment of fixed capital goods are generally carried out, in the short-run, these can be ignored. Therefore, the short-run problem of linear programming problem (15) can be expressed as follows.

$$\max\{pF \mid \frac{1}{1+r}p \leq pA + L,\, p \geq \mathbf{0}\} \tag{17}$$

When $g = r$, the dual problem in the short run will be expressed as follows:

$$\min\{Lq \mid \frac{1}{1+r}q \geq Aq + F,\, q \geq \mathbf{0}\} \tag{18}$$

3.2 Calculation procedure

(1) Calculate the bundle of wage goods F and labor input vector L.

The product of the annual total working population N_0 and annual working hours h per person gives the total working hours in a year; that is,

$$H = N_0 h.$$

The bundle of wage goods per person is the consumption divided by the total working population. In other words, this is equal to $\frac{C_i}{N_0}$. As for wage goods per unit of labor,

$$f_i = \frac{C_i}{H}.$$

The bundle of wage goods is $F = (f_i)$.

Further, the total added value V_0 is

$$V_0 = \sum_{j=1}^{n} W_j + \sum_{j=1}^{n} V_j + \sum_{j=1}^{n} T_j,$$

however, W, V and T are wage, profit and tax of an input-ouput table respectively. The working hours per unit value is considered as $\frac{H}{V_0}$, and the working hours in sector j is $(W_j + V_j + T_j)\frac{H}{V_0}$. Therefore, the labor input necessary to produce one unit becomes

$$l_j = \frac{H(W_j + V_j + T_j)}{V_0 X_j}.$$

The labor input vector is $L = (l_j)$.

(2) Find the optimum solution for the long-run linear programming problem and draw the wage-profit curve.

Change r in the range $0 \leq r \leq g^*$, solve the long-run standard maximum problem (15), and find the optimum solution p^*. [9]

The long-run wage-profit curve can be expressed as $(\frac{1}{p^*F}, r)$.

(3) Find the optimum solution for the short-run linear programming problem and draw the wage-profit curve.

Change r in the range $0 \leq r \leq g_{max}$ and find the optimum solution p^* for the standard maximum problem (17).

Similarly, the short-run wage-profit curve is expressed as $(\frac{1}{p^*F}, r)$.

3.3 Calculation result

3.3.1 The maximum growth rate

The Chinese economy's maximum (potential) growth rate and macro marginal capital-output ratio are shown in Table 1.

Table 1: Basic macro parameters (1987-2000)

	1987	1990	1992	1995	1997	2000
maximum (potential) growth rate (%)	40.3	35.5	31.9	30.3	30.5	26.6
macro marginal capital-output ratio (%)	35.2	35.6	45.3	48.1	42.6	58.4

From Table 1 we see that when the economy achieves its highest growth rate, the production of luxuries is not carried out.

3.3.2 Wage-profit curve à la von Neumann-Leontief

The long- and short-run wage-profit curves à la von Neumann-Leontief are shown in Table 2 and Table 3, respectively. The wage-profit curves from 1987 to 2000 based on the above-mentioned calculations are shown in Figures 2-7.

3.3.3 Source of main data

In this paper, the gross investment matrix of each year in China is adjusted with a sector classification: the 33-sector input-output tables for 1987, 1990, 1992, 1995 and the 40-sector input-output tables for 1997, 2000 are integrated as a 24-sector input-output table. The input-output table data used were published by the National Bureau of Statistics of China (NBSC), and the gross investment matrix data were estimated by Lü (2007). The data on the durability of fixed capital used were published by Ministry of Finance of China (1992) and State Council of China (2007). The details of the input-output tables and durability of fixed capital are shown in Table 4.

The data on the total working population are from the NBSC publication *China Statistical Yearbook 2003*, and the data on the annual working hours per person are from the international labor office (ILO) publication *Yearbook of Labour Statistics 2003*.

[9] Now, it asks for a depreciation rate, as follows. If $r = 0$ then $\psi_i = \frac{1}{\tau_i}$. If $r > 0$ then $\psi_i = \frac{r}{(1+r)^{\tau_i}-1}$.

Table 2: The long-run wage-profit relationships (1987-2000)

r	$1/pF$					
	1987	1990	1992	1995	1997	2000
0.00	1.790	1.849	1.935	1.904	1.958	1.889
0.02	1.701	1.752	1.815	1.781	1.836	1.754
0.04	1.613	1.656	1.695	1.658	1.715	1.619
0.06	1.526	1.561	1.577	1.535	1.593	1.482
0.08	1.441	1.466	1.459	1.413	1.472	1.345
0.10	1.356	1.372	1.341	1.291	1.351	1.207
0.12	1.272	1.278	1.224	1.169	1.230	1.068
0.14	1.188	1.184	1.107	1.047	1.108	0.929
0.16	1.105	1.089	0.989	0.925	0.985	0.788
0.18	1.022	0.993	0.872	0.802	0.860	0.645
0.20	0.939	0.896	0.753	0.678	0.734	0.501
0.22	0.855	0.797	0.633	0.552	0.604	0.353
0.24	0.771	0.695	0.511	0.424	0.472	0.201
0.26	0.686	0.590	0.387	0.293	0.334	0.045
0.28	0.600	0.480	0.260	0.158	0.191	
0.30	0.511	0.364	0.130	0.018	0.040	
0.32	0.420	0.240				
0.34	0.326	0.107				
0.36	0.228					
0.38	0.124					
0.40	0.014					

Table 3: The short-run wage-profit relationships (1987-2000)

r	$1/pF$					
	1987	1990	1992	1995	1997	2000
0.00	1.868	1.929	2.103	2.065	2.096	2.062
0.05	1.685	1.729	1.867	1.825	1.854	1.813
0.10	1.518	1.546	1.649	1.604	1.631	1.582
0.15	1.365	1.376	1.447	1.399	1.425	1.367
0.20	1.223	1.219	1.258	1.208	1.232	1.166
0.25	1.093	1.071	1.080	1.028	1.051	0.976
0.30	0.971	0.932	0.911	0.858	0.879	0.796
0.35	0.857	0.799	0.751	0.696	0.715	0.622
0.40	0.750	0.672	0.596	0.540	0.557	0.454
0.45	0.648	0.548	0.445	0.389	0.404	0.290
0.50	0.552	0.426	0.298	0.241	0.252	0.128
0.55	0.460	0.304	0.152	0.095	0.102	
0.60	0.371	0.179	0.006			
0.65	0.285	0.050				
0.70	0.201					
0.75	0.117					
0.80	0.034					
g_{max}	0.820	0.668	0.602	0.582	0.583	0.539

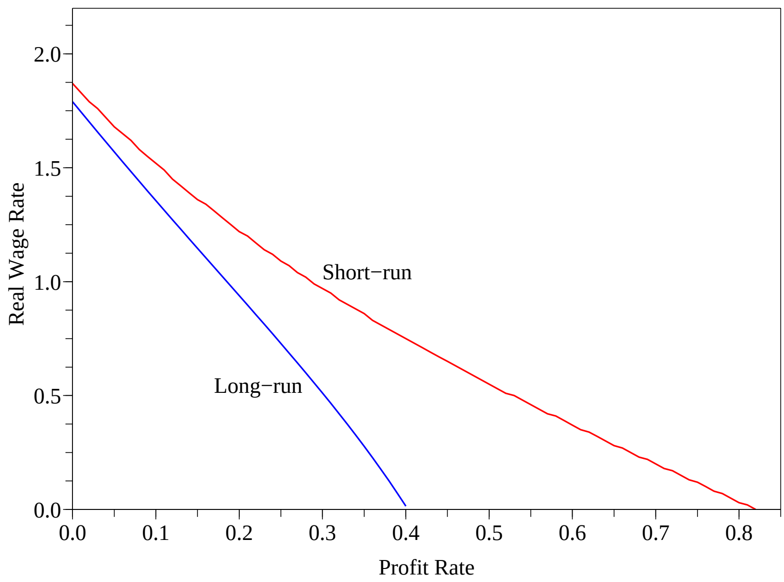

Figure 2: The wage-profit curve à la von Neumann-Leontief (1987)

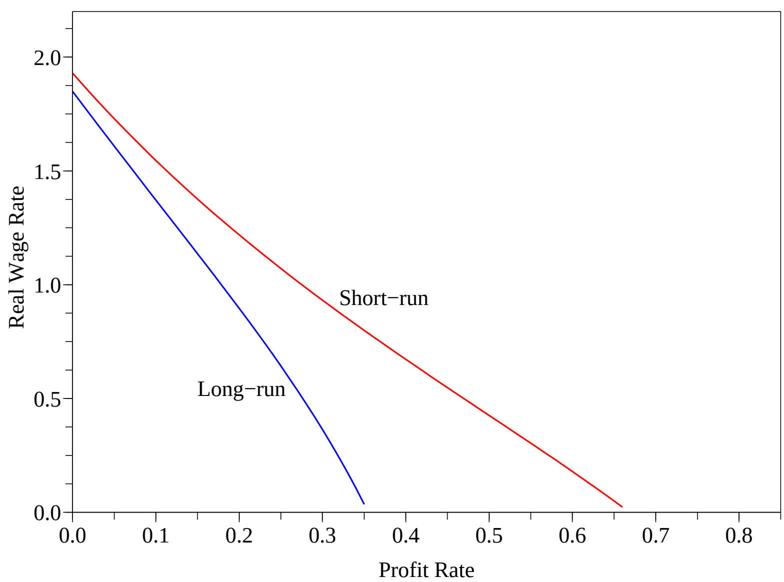

Figure 3: The wage-profit curve à la von Neumann-Leontief (1990)

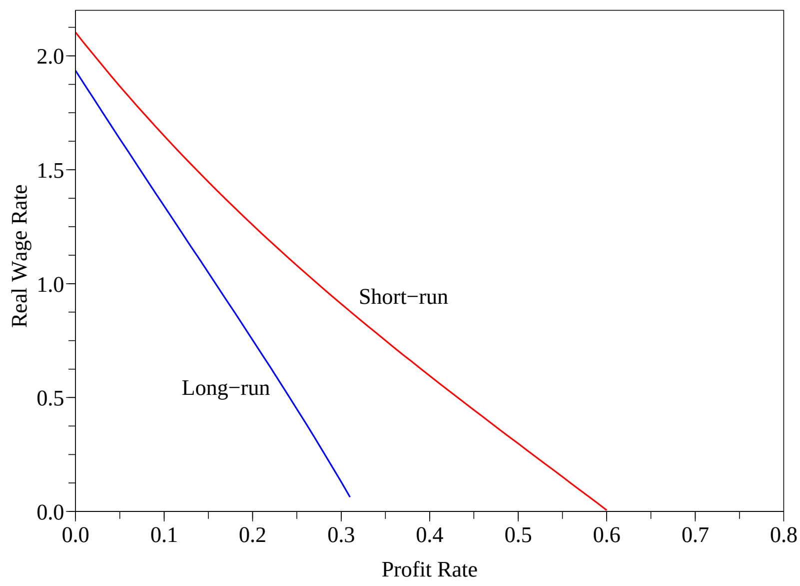

Figure 4: The wage-profit curve à la von Neumann-Leontief (1992)

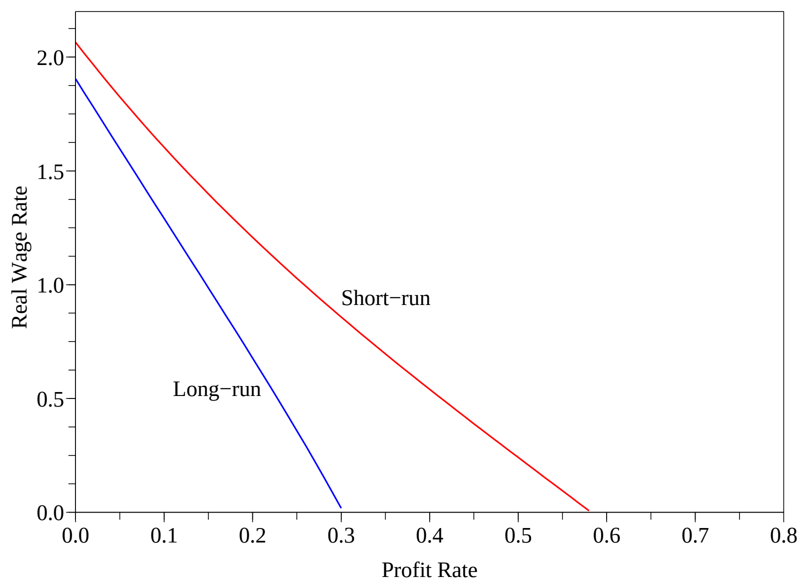

Figure 5: The wage-profit curve à la von Neumann-Leontief (1995)

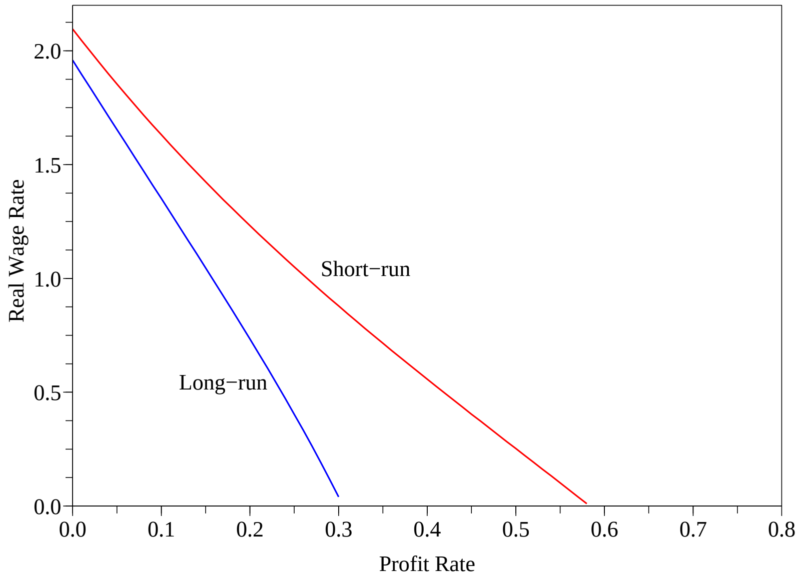

Figure 6: The wage-profit curve à la von Neumann-Leontief (1997)

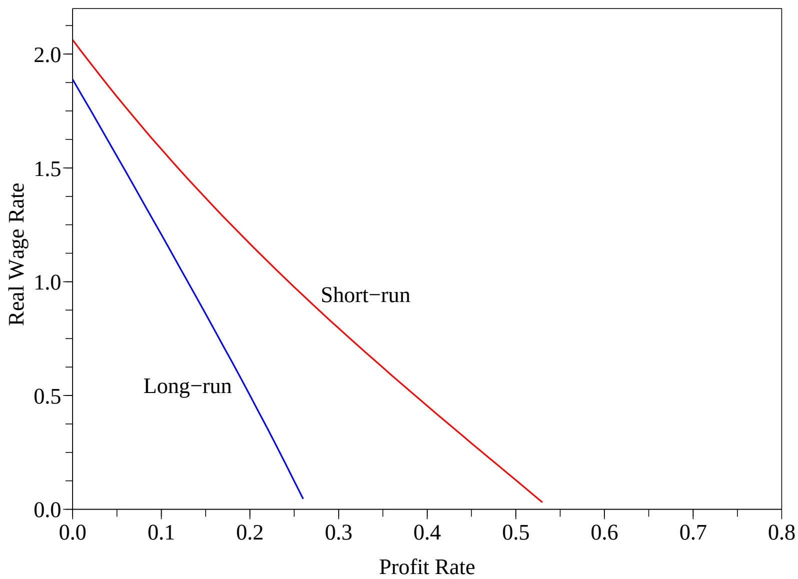

Figure 7: The wage-profit curve à la von Neumann-Leontief (2000)

Table 4: Codes and durabilities of 24 sectors

Code	Sectors	Durabilities (years)
1	Agriculture	16
2	Mining	
3	Foods and tabacco	
4	Textiles	
5	Pulp and papers	
6	Electrity, steam and hot water	
7	Petroleum and coal	
8	Coal gas and coal product	
9	Chemicals	
10	Nonmetallic mineral products	
11	Metals smelting and prossing	
12	Metal products	12
13	General machinery	17
14	Transportation machinery	9
15	Electric machinery	17
16	Precise machinery	15
17	Other manufactured products	12
18	Construction	40
19	Transportation	13
20	Commercial	10
21	Services	
22	Finance, insurance and real estate	
23	Education, health and scientific research	
24	Public administration	

Note: Blanks in the durability column indicate that goods concerned are non-durable.

4 Conclusion

In this paper, we estimated China's fixed capital coefficient using the Sraffa-Fujimori method and calculated the economy's wage-profit curve in a von Neumann-Leontief system.

The following points relating to the Chinese economy are clear from our calculations and theoretical parameters.

(1) The short-run maximum profit rate and long-run maximum (potential) growth rate tends to decrease from the 1980s through the 2000s.

(2) The maximum (real) wage rate tends to increase from the 1980s through the 2000s.

(3) Each year's long-run wage-profit curve is within its short-run wage-profit curve. In other words, the short-run real wage rate is greater than the long-run one, the profit rate remaining the same. Further, the short-run profit rate is greater than the long-run one, the real wage rate remaining the same.

(4) The long-run wage-profit curves gradually shifted to the lower left area over 1987 through 2000.

(5) The marginal capital-output ratio has increased over 1987 through 2000.

In this paper, theoretical restrictions exist because we assume presuppositions such as the invariable efficiency of fixed capital. However, by using actual parameters instead of theoretical parameters, these calculations can have significant importance for actual economic interpretation.

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