Structural Change and Aggregate Investment Rate

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Abstract

This paper explores the role of structural change model in accounting for the dynamic pattern of aggregate investment rate. A three-sector general equilibrium model with Stone-Geary preferences and uneven TFP growth is build to establish a link between structural change and investment decisions. The model rationalizes the relationship between rising investment rate and labor reallocation and shows that the increasing investment rate actually can be resulted from structural transformation. The paper mainly focuses on the case of China and conduct the quantitative analysis. The quantitative results show that the aggregate investment rate which is endogenously generated by the model can well replicate the increasing investment rate over time.

Keywords: structural change, investment rate, transitional dynamics

JEL Classification: E13, E22, O11, O41

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1 Introduction

Capital accumulation is an important factor to account for economic growth and development. Historical data shows that the investment-to-output ratios for US and UK rose substantially with industrialization (Laitner, 2000). New emerging Asian economies such as Japan, Korea and Taiwan also display a rapid increasing investment rate after the economies took off. Moreover, the time series patterns of aggregate investment rate in these countries feature a hump-shaped path, which is similar as the evolution of manufacturing value added share and employment share (see Figure 1). Recently China has become the second largest economy and almost fifty percent of its GDP is driven by investment. It is argued that these Asian growing miracles are mainly supported by increasing investment rate. Then an interesting question would be raised: can neoclassical model rationalize the dynamic pattern of investment rate in these countries?

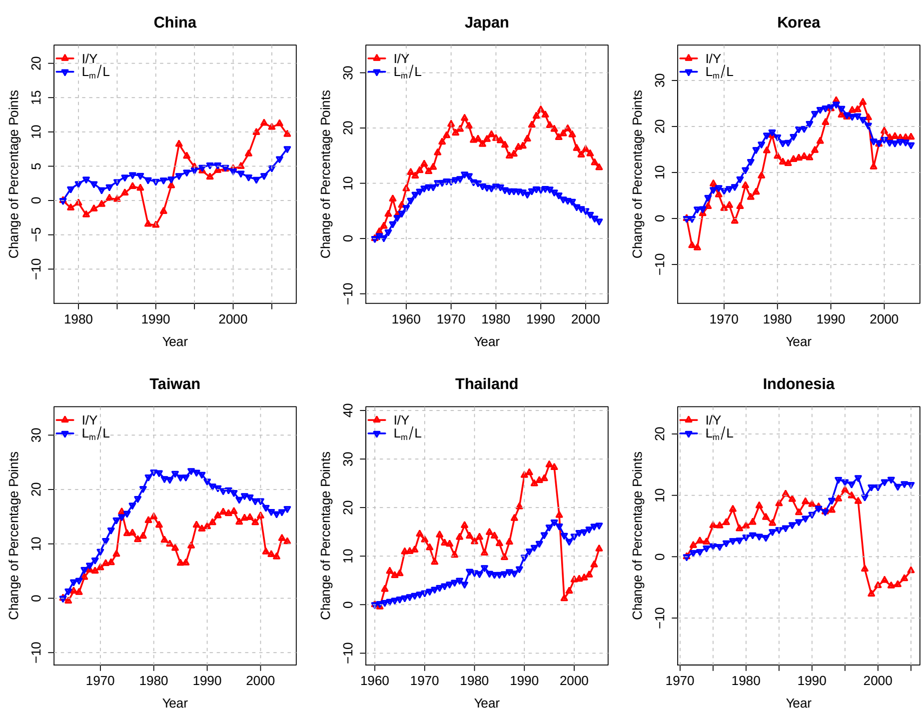

Figure 1: Aggregate Investment Rate and Manufacturing Employment Share

However, above empirical evidence is inconsistent with the results of most of standard neoclassical growth models. The basic neoclassical model of capital accumulation predicts that the initial investment rate is high and it is decreasing over time due to declining capital return, and the transition to the steady state is rapid (King and Rebelo, 1993).[1]

[1] Given that the initial capital stock is low enough, the investment rate is decreasing over time.

This paper explores the role of structural change model in accounting for the dynamic pattern of aggregate investment rate. A three-sector general equilibrium model with Stone-Geary preferences and uneven TFP growth is build to establish a link between structural change and investment decisions. Only manufacturing goods can be invested. As a result, investment rate would show a similar transition path as manufacturing employment share and value added share. The intuition is as follows: 1) by separating consumption sector and capital sector (with different production technologies and uneven TFP growth), the relative price of investment goods are decreasing over time, which results in an increasing investment rate at the beginning; 2) the introduction of Stone-Geary preferences also comes out with varying income elasticity and intertemporal elasticity of substitution over time, which can generate hump-shape investment rate.

The paper mainly focuses on the case of China and conduct the quantitative analysis. The quantitative results show that the aggregate investment rate which is endogenously generated by the model can well replicate the increasing investment rate over time. China has grown rapidly over the past three decades and now become the second largest economy in the world. A growing literature documents try to investigate the source of China's rapid growth and discuss whether its growth is sustainable. Some of them suggest that TFP growth and labor reallocation play an important role in this process while other analyses emphasize the role of rising investment. This paper rationalizes these two viewpoints and shows that the increasing investment rate actually can be resulted from structural transformation. Therefore given the fact that there are still massive employment in the rural area, is is highly possible that the investment rate will keep increasing, and the return to capital will keep increasing. As a result, China's growth is likely to be sustained.

I also compare the prediction of the model with multiple countries such as Japan which displays a decreasing investment rate after 1970s. Due to the rapid increase of the service sector, the relative price of investment goods (manufacturing goods) declines quickly, which results in a decreasing investment rate (decreasing part of a hump-shape path).

Related literature This paper is related to existing literature on structural change, and transitional dynamics of economic growth, and development of China.

The idea that labor reallocation and investment decision correlate with each other is first introduced by Lewis (1954). It presents a simple dual-sector economic development model, in which capital formation occurs due to a large number of rural surplus labor are absorbed by the rapid growing capitalist sector. Laitner (2000) is another closely related paper which uses Stone-Geary Type preferences to explain the rising saving rate in US. He stresses the role of land in the transition while this paper does not. King and Rebelo (1993) conducts several numerical exercises to investigate the strength and weakness of various neoclassical model. This paper follows their analysis and combines the mechanism together with structural change models. Chang and Hornstein (2013) uses a two-sector model with Stone-Geary utility model to explain the transition dynamics of Korea's case. Comparing to their model, this paper endogenizes the change of relative price of investment goods by introducing the service sector.

This paper is also related to Brandt and Zhu (2010) which accounts for China's growth using a three-sector model. Unlike their model, this paper endogenizes the investment decision and connects labor reallocation and rising investment rate.

This paper is organized as follows. Section 3 presents the model formally. Section 4 explains the calibration procedure and reports the quantitative results. Section 5 summarizes and concludes.

2 Motivational Backgrounds

This section provides motivational backgrounds from two aspects: empirics and theory. I first introduce the two important macro trends which can potentially account for the rapid growth in China. Then I show the importance to investigate how capable of structural change models in accounting for the growth dynamics of capital accumulation.

2.1 Structural Change and Increasing Investment Rate

China has been experienced rapid growth rate for the past 30 years. A growing literature has been motivated to study the driving forces behind this unprecedented growth miracle. Among the research, two of the most salient trends have been documented to explain the source of growth: one is high and increasing saving and investment rate and the other one is rapid massive reallocation of labor across sectors.

Figure 2 shows the high and increasing saving and investment rate in China from 1978 to 2007.[2] The investment rate increases from less than 30 percent in 1978 to more than 40 percent in 2007. There has been a significant increase since the early 1990s. It is argued that the high GDP growth in China is dominated by high investment growth.[3] The pattern of high and increasing investment rate is also documented in other Asian growth miracles, such as Hong Kong, Singapore, Korea and Taiwan, in which capital accumulation played a fundamnetal role (Young (1995)).

[2]The gap between saving and investment is mainly because of changes in inventory and foreign reserve.
[3]See Prasad and Rajan 2006; Prasad 2011 among many others.

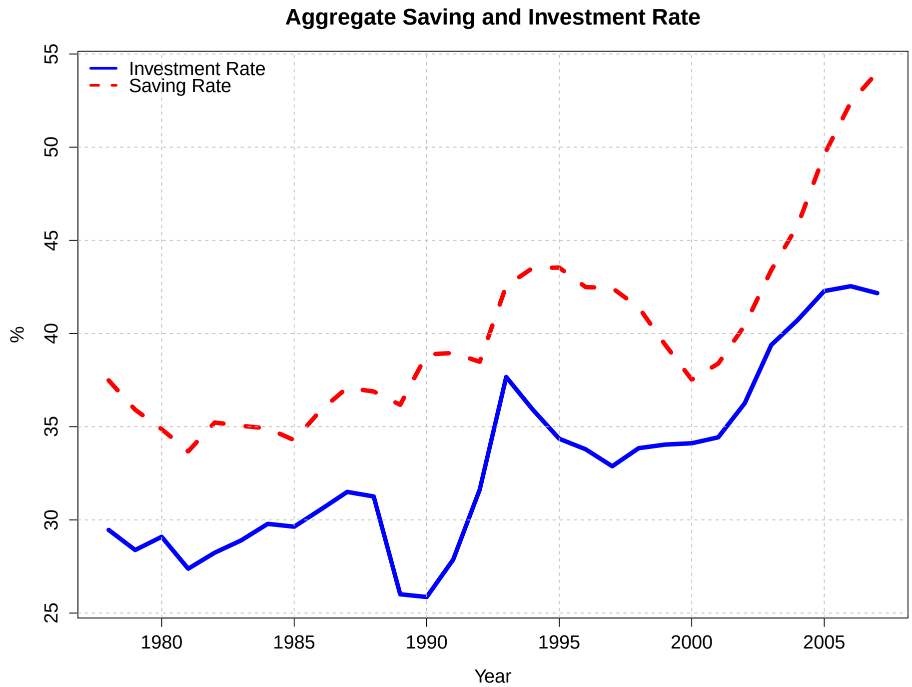

Figure 2: Aggregate Saving and Investment Rate
Notes: Investment rate is defined as gross fixed capital formation (GFCF) over GDP. Saving rate is defined as one minus aggregate domestic consumption over GDP. All variables are measured in nominal value. Source: Various issues of Statistical Yearbook of China.

Although investment rate has been high and increasing, the return to capital has not declined (see Figure 3).

Figure 4 shows the macro trend of labor reallocation in China from 1978 to 2007. The employment share in agriculture has gradually declined from about 70 percent in 1978 to 40 percent in 2007.[4]

Due to different labor productivities across sectors, this massive labor reallocation from agriculture to non-agriculture could contribute to aggregate growth in China.[5]

Since growth of TFP, capital and labor are all inter-related, they should not be studied independently. This paper tries to provide a unified framework for understanding the connection between labor reallocation and increasing investment rate as well as high growth in China. Since the non-agricultural sectors accumulate capital faster than the agricultural sector (see Figure 5), the aggregate capital deepening process could be resulted from the movement of labor from rural to urban areas.

[4]The figures are based on official data reported by the National Bureau of Statistics in China (NBS). Brandt, Tombe and Zhu (2013) argues that NBS data overestimate the employment share in agriculture. Their estimates suggest that agricultural labor force had declined to 26.2% by 2007.

[5]See Brandt, Hsieh and Zhu 2008; Cao and Birchenall 2013 among many others.

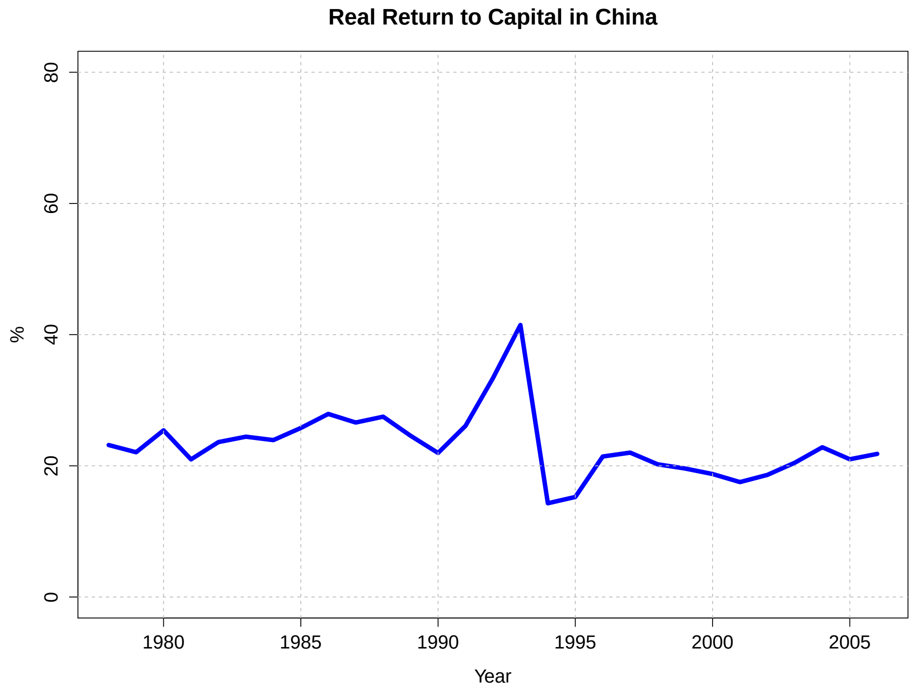

Figure 3: Return to Captial in China
Source: Various issues of Statistical Yearbook of China and author's own calculation.

2.2 Transitional Dynamics of Neoclassical Model

Neoclassical model provides an important theoretical and empirical framework for studying the source of economic growth and development. As King and Rebelo (1993) pointed out, to plausibly explain the differences in economic growth over time and across countries, it is worth exploring the quantitative implication of various neoclassical models.

However, the quantitative predictions of most standard growth model are not consistent with the empirical evidence, especially that from Asian emerging countries. Cross-country empirics show that convergence to the steady state is quite slow and investment rate displays a hump-shaped path, while the standard one-sector growth model implies a rapid transition to the steady state capital level, decreasing investment rate, and initially high and then decreasing real interest rate due to diminishing capital return (King and Rebelo, 1993).

Structural change theories provide sufficient ingredients for neoclassical model to account for above transitional dynamics.[6] One class of structural change models emphasizes the role of non-homothetic preferences: the income elasticity of demand for agricultural goods is

[6]Here I explain the increasing investment rate from structural transformation perspective. There are also some other treatment. Buera and Shin (2013) quantitatively analyzes the role of financial frictions and resource misallocation in explaining development dynamics. Their model can successfully generate the hump-shaped path of investment rate.

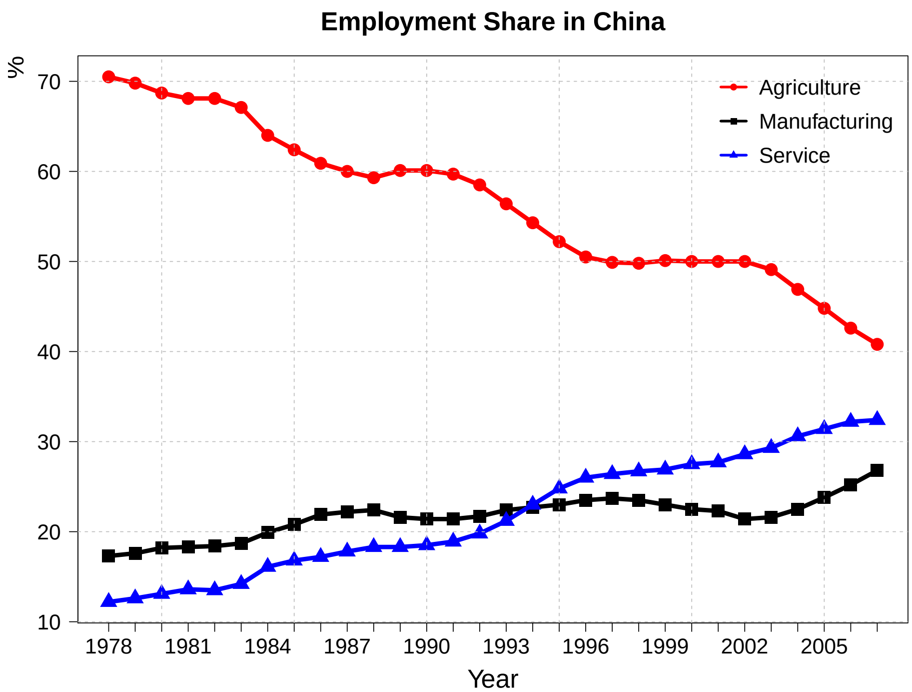

Figure 4: Employment Share by Sector: 1978-2007
Source: Various issues of Statistical Yearbook of China.

decreasing, i.e., Engel's law (see Kongsamut, Rebelo and Xie (2001); Gollin, Parente and Rogerson (2002)). The other class of models features uneven productivity growth across sectors, which results in rich patterns of relative price change and demand (if elasticities of substitution across goods are not equal to one, see Ngai and Pissarides (2007); Acemoglu and Guerrieri (2008)). Both of the two perspectives can help us understand the development dynamics. On the one hand, by introducing non-homothetic preferences (such as Stone-Geary utility function), the intertemporal elasticity of substitution, which governs the decision of household saving, is not constant. Evidence shows that marginal propensity to save rises with wealth and minimum consumption level (usually food) is required to explain this pattern (Atkeson and Ogaki (1996); Alvarez-Pelaez and Díaz (2005)). On the other hand, uneven productivity growth can generate rich pattern of relative price of investment goods (produced mainly by the manufacturing sector), hence affects the capital return dynamics.[7]

Moreover, by separating capital sector and consumption sector with different capital intensities, the model can also generate increasing investment rate (King and Rebelo, 1993). Given the fact that capital intensity is much lower in agriculture than in non-agriculture, as

[7] **?** shows that the relative price of investment is negatively correlated with investment rates across countries. Chang and Hornstein (2013) finds that the relative price of investment is quantitatively important in accounting for capital accumulation in Korea.

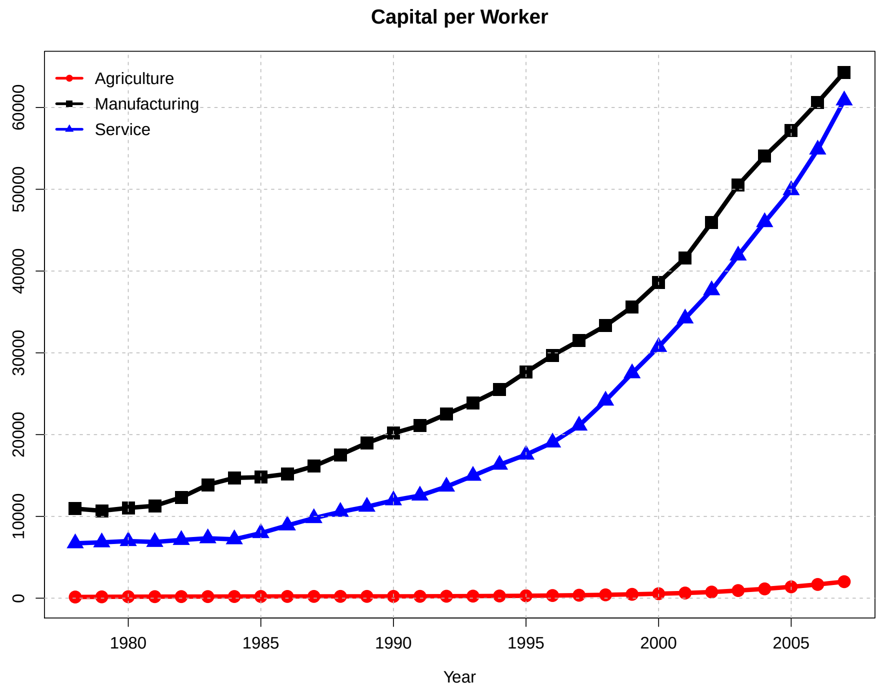

Figure 5: Capital Labor Ratio by sectors
Source: Various issues of Statistical Yearbook of China.

resources shift from agriculture to non-agriculture, physical capital becomes more and more attractive than farm land, i.e., "structural change accompanying growth may have caused the rise in saving rates" (Laitner, 2000).

In sum, it is appealing to investigate how capable of structural change models in accounting for the growth dynamics of capital accumulation both qualitatively and quantitatively. It is also important to evaluate the role of different channels in this transitional process.

3 Model

This section presents a general equilibrium model with structural change features. The model incorporate both demand side and supply side mechanism such as subsistence requirement in agriculture, approximation of home production, and uneven TFP growth and capital deepening in production.

I consider a closed economy with three sectors: agriculture (a), manufacturing (m), service (s). Each sector produces corresponding commodities for consumption and only the manufacturing sector can produce investment goods, which are needed as inputs by all sectors. Capital income share and exogenous TFP growth can be different across sectors. The economy has an identical , infinitely lived household. Time is discrete and starts from

0.

The model establish a link between structural transformation and aggregate investment decisions. As the economy grows, resources move out from agriculture to non-agriculture, and eventually shift to the service sector. During this process,

3.1 Technologies

In each period t there are three goods produced: agriculture (a), manufacturing (m), and services (s). The production function in sector $i \in \{a, m, s\}$ is

$$Y_{it} = A_{it} K_{it}^{\theta_i} L_{it}^{1-\theta_i}, i \in \{a, m, s\},$$

where $\theta_i \in \{a, m, s\}$ is physical capital income share and it can be different across sectors. The TFP parameter A_{it} grows exogenously. The manufacturing goods Y_m can be both consumed and invested. by separating consumption sector and capital sector (with different production technologies and uneven TFP growth), the relative price of investment goods are decreasing over time, which results in an increasing investment rate at the beginning. The evolution of capital stock satisfies

$$\begin{aligned} K_{t+1} - (1-\delta) K_t + C_{mt} &\leq Y_{mt}, \\ K_{at} + K_{mt} + K_{st} &= K_t, \end{aligned}$$

where $K_0 > 0$ is given, $\delta > 0$ is the capital depreciation rate, and C_m is the consumption of manufacturing goods.

I assume the good markets are competitive and capital is perfectly mobile. The data shows that the wage rate is different across sectors which implies frictions in the labor market. Here I consider this distortion in the labor market as mobility costs, which capture rural-urban migration costs, sectoral entry costs or skill requirements across sectors.[8] The cost is defined as a fraction of the wage rate in the manufacturing sector:

$$w_{it} = (1 - \mu_{it}) w_{mt}, i \in \{a, s\}.$$

It means that in each period, if a worker wants to move from sector i, $i \in \{a, s\}$ to the manufacturing sector, he or she has to give up a fraction of μ_i of the marginal product of labor in the manufacturing sector.

[8] Taking China for example, the migration from rural area to urban area is restrictive over time. Meanwhile the marginal product of labor is also kept higher by the government in the state sector than the non-state sector, see Brandt and Zhu (2010) for the detailed discussion.

At each date t, given the price p_{it}, $i \in \{a, m, s\}$, wage rate w_{it} and capital rental rate r_t, the profit maximization problem for a representative firm in sector i is

$$\max_{L_{it}, K_{it}} \{p_{it} Y_{it} - w_{it} L_{it} - r_t K_{it}\}. \quad (1)$$

3.2 Preferences

The economy has an infinitely lived representative household who is endowed with one unit of labor each period. Labor is supplied inelastically hence the total labor supply is equal to one each period. The household consumes agricultural goods C_a and nonagricultural goods C_n:

$$U(C_{at}, C_{nt}) = \begin{cases} C_{at}, & \text{if } C_{at} \leq \bar{a} \\ \bar{a} + \ln C_{nt}, & \text{if } C_{at} > \bar{a} \end{cases},$$

where $\bar{a} > 0$ is the subsistence requirement for agricultural consumption. When agricultural productivity is such low that $C_{at} < \bar{a}$, the representative household can only consume the agricultural good; otherwise, the household could gain utility from the consumption of nonagricultural goods C_n. This simplified specification of utility function for agricultural goods makes the analysis more tractable and it can capture the decline of agricultural employment observed in the data remarkably well. I assume the initial agricultural labor productivity is high enough to make the economy operate above the subsistence level. As a consequence, the income elasticity of demand for agricultural goods is less than one, which is consistent with Engel's law. [9] Moreover, the introduction of Stone-Geary preferences also comes out with varying income elasticity and intertemporal elasticity of substitution over time, which can generate hump-shape investment rate.

The nonagricultural good C_n is a composite consumption of manufacturing goods C_m and services C_s:

$$C_{nt} = \left[\phi C_{mt}^{\frac{\epsilon-1}{\epsilon}} + (1-\phi)(C_{st} + \bar{s})^{\frac{\epsilon-1}{\epsilon}}\right]^{\frac{\epsilon}{\epsilon-1}},$$

where $\phi \in (0, 1)$, and $\epsilon > 0$ is the elasticity of substitution between manufacturing goods C_m and services C_s. Given $\bar{s} > 0$, the income elasticity of service consumption C_s is larger than one. This specification is used to capture a constant level of service production at home.[10]

[9] This simplification can be seen in Laitner (2000) and Gollin, Parente and Rogerson (2002) among many others.

[10] For similar setup, see Kongsamut, Rebelo and Xie (2001); Duarte and Restuccia (2010). For alternative specification of home production, see Rogerson (2008); Gollin, Parente and Rogerson (2004).

The lifetime utility maximization problem is

$$\max_{C_{it}} \sum_{t=0}^{\infty} \beta^t U\left(C_{it}\right), \tag{2}$$

s.t.

$$p_{at}C_{at} + p_{mt}\left(C_{mt} + X_t\right) + p_{st}C_{st} \;=\; \sum_{i\in\{a,m,s\}} w_{it}L_{it} + r_t K_t,$$

where $\beta \in (0,1)$ is the discount factor and $X_t = K_{t+1} - (1-\delta) K_t$ is the capital investment.

3.3 Equilibrium

The following market clearing conditions hold in each period t:

- Goods markets

$$\begin{aligned} Y_{it} &= C_{it}, i \in \{a, s\}, \\ Y_{mt} &= C_{mt} + X_t. \end{aligned} \tag{3}$$

- Capital market

$$K_t = \sum_{i\in\{a,m,s\}} K_{it}. \tag{4}$$

- Labor market

$$1 = \sum_{i\in\{a,m,s\}} L_{it}. \tag{5}$$

The competitive equilibrium of this economy is defined on TFP parameters $\{A_{at},\, A_{mt},\, A_{st}\}$ and structural parameters $\{\theta_a,\, \theta_m,\, \theta_s\}$, $\{\mu_{at},\, \mu_{st}\}$, ϵ, ϕ, δ, β, $\bar{a}$, $\bar{s}$ as follows.

Definition 1. A competitive equilibrium is a sequence of goods prices $\{p_{at},\, p_{mt},\, p_{st}\}$, factor prices $\{w_{at},\, w_{mt},\, w_{st},\, r_t\}$, and labor and goods allocations $\{L_{at},\, L_{mt},\, L_{st},\, C_{at},\, C_{mt},\, C_{st},\, Y_{at},\, Y_{mt},\, Y_{st},\, X_t\}$, such that given prices and $K_0 > 0$, the allocation solves the representative firm's maximization problem (1), the representative household's maximization problem (2), and satisfy the market clearing conditions (3)-(5).

The competitive equilibrium exists and is unique. The equilibrium prices can be described as follows:

$$
\begin{aligned}
w_{it} &= (1-\theta_i)\, p_{it} A_{it} \left(\frac{K_{it}}{L_{it}}\right)^{\theta_i}, j \in \{a, m, s\} \\
r_t &= \theta_i p_{it} A_{it} \left(\frac{K_{it}}{L_{it}}\right)^{\theta_i - 1}, j \in \{a, m, s\} \\
\frac{p_{mt}}{p_{st}} &= \frac{\phi}{1-\phi} \left(\frac{C_{mt}}{C_{st} + \bar{s}}\right)^{-\frac{1}{\epsilon}}.
\end{aligned}
$$

The marginal rate of technical substitution should satisfy

$$
\frac{1}{1-\mu_{at}} \frac{1-\theta_a}{\theta_a} \frac{K_{at}}{L_{at}} = \frac{1-\theta_m}{\theta_m} \frac{K_{mt}}{L_{mt}} = \frac{1}{1-\mu_{st}} \frac{1-\theta_s}{\theta_s} \frac{K_{st}}{L_{st}}.
$$

The optimal consumption rule of C_m is determined by

$$
\frac{p_{m,t+1} C_{m,t+1}}{p_{mt} C_{mt}} = \beta \left[\frac{r_{t+1}}{p_{t+1}} + (1-\delta) \right].
$$

4 Quantitative Analysis

This section quantitatively assess the relationship between structural change process and aggregate investment rate. I first calibrate most of the model parameters to match the data of China. Then I conduct several quantitative analyses to show the explanatory power of this model.

4.1 Calibration

I calibrate the model to capture the main structural change patterns of China from 1978 to 2007.[11] Parameters that need to be determined are: TFP parameters $\{A_{at}, A_{mt}, A_{st}\}$ and structural parameters $\{\theta_a, \theta_m, \theta_s\}$, $\{\mu_{at}, \mu_{st}\}$, ϵ, ϕ, δ, β, $\bar{a}$, $\bar{s}$. The main calibration goal is to calibrate these parameters to capture the important features of sectoral employment share. Manufacturing goods are set to be the numeraire, that is, $p_{mt} = 1$.

I follow the literature and pick $\beta = 0.95$, $\delta = 0.05$ for the whole quantitative analysis. The sectoral capital income shares θ_i, $i \in \{a, m, s\}$ is computed from the average data of input-output table issued by various yearbooks. The capital income share is caluclated as

[11] The consideration that I choose 1978 as the beginning year is data availability. See Appendix A.1 for the data source. Unlike some some literature (see Duarte and Restuccia (2010); Chang and Hornstein (2013) for example), The time series data here are not trended with HP filter. Since there were huge productivity shocks (i.e., institutional reform, financial crisis, etc.) behind those Asian emerging miracles, HP filter is not appropriate for the purpose of this paper and the results could be misleading.

one minus labor income share, which is labor compensation divided by value added net of production tax. We have $\theta_a = 0.15$, $\theta_m = 0.60$, and $\theta_m = 0.52$. We should notice that agriculture does not depend much on capital, and the service sector is less capital intensive than the manufacturing sector.

Sectoral wage rate is equal to sectoral marignal product of labor. Then given θ_i, labor market distortions can be backed out by

$$1 - \mu_{it} = \frac{w_{it}}{w_{mt}} = \frac{\frac{(1-\theta_i) p_{it} Y_{it}}{L_{it}}}{\frac{(1-\theta_m) p_{mt} Y_{mt}}{L_{mt}}}.$$

The average wage gap between agriculture and manufacturing $(1 - \mu_a)$ is 0.39, and the average wage gap between service and manufacturing $(1 - \mu_s)$ is 0.87. This implies a large gap between agriculture and non-agriculture. Figure 6 shows the time series of the wage gap.

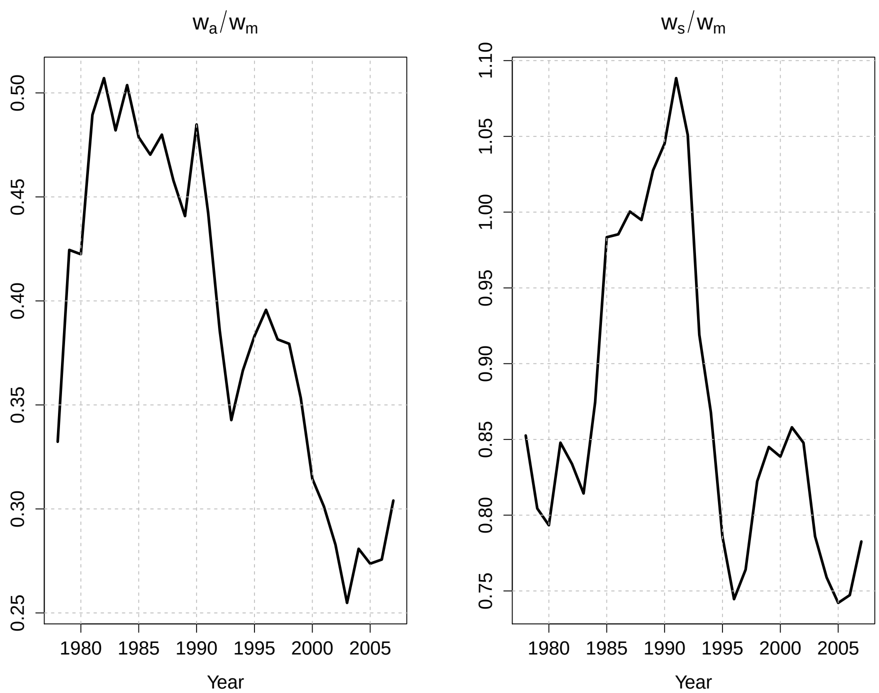

Figure 6: Labor Market Frictions

I use average value of μ_{it} and assume constant TFP growth rate to estimate the preference parameters ϵ and ϕ. That is, $A_{it} = A_{i0} (1 + \gamma_i)^t$. γ_i is estimated from sectoral growth accounting exercises. For the agricultural sector, I assume the output is constant to be consistent with the model. $\gamma_a = 0.0035$, $\gamma_m = 0.051$, and $\gamma_s = 0.0087$. Notice that $\gamma_m > \gamma_s$ and $\theta_m > \theta_s$, so labor moves from the manufacturing sector to the service sector due to both uneven TFP growth and capital deepening effect.[12] Given A_{it}, I choose $\bar{a} = 1.196$ and $\bar{s} = 416.9$ to match the initial value of the agricultural and service employment share. Then I restrict ϵ and ϕ to match the manufacturing and service employment share over time. $\phi = 0.000037$ and $\epsilon = 0.125$. Table 1 reports all the calibration values.

Table 1: Parameter Value

Parameter	Target
$\theta_a = 0.15$, $\theta_m = 0.60$, $\theta_m = 0.52$	Input-output table
$\bar{a} = 1.196$, $\bar{s} = 416.9$	Initial value of employment share
$\phi = 3.7 \times 10^5$, $\epsilon = 0.125$	Manufacturing and service employment share
$\delta = 0.05$, $\beta = 0.95$	From the literature

4.2 Results

The dynamic patterns of structural change feature which we observe fromt the data are captured well by the quantitative model. Figure 7 shows the results. Employment share in agriculture decreases over time after 1978. At the same time, manufacturing and service employment share increase rapidly, and service employment share surpasses manufacturing in 1995.

Under the setup of calibration, that is, TFP grows at a constant rate, and wage gap is constant, the model predicts an increasing aggregate investment rate (see Figure 8).

Although the simualtion result shows the same increasing pattern as we observed in the data, there is a large gap between the results and the data. This is because various TFP shocks and frictions are not considered in this simple exercise. Given the structural parameters in Subsection 4.1, now I calibrate the TFP values of manufacturing (A_{mt}) to exactly match the manufacturing employment share and let labor market frictions (μ_{it}) vary over time. The calibrated A_{mt} is shown in Figure 9.

Given the calibrated manufacturing TFP series, now the model can well capture the ever-changing pattern of aggregate investment rate. Figure 10 shows the results.

China has grown rapidly over the past three decades and now become the second largest economy in the world. A growing literature documents try to investigate the source of China's rapid growth and discuss whether its growth is sustainable. Some of them suggest that TFP growth and labor rellocation play an important role in this process while other analyses emphasize the role of rising investment. My paper rationalizes these two viewpoints and shows that the increasing investment rate actually can be resulted from structural transformation. Therefore given the fact that there are still massive employeemnt in the rural area,

[12] See Ngai and Pissarides (2007) and Acemoglu and Guerrieri (2008).

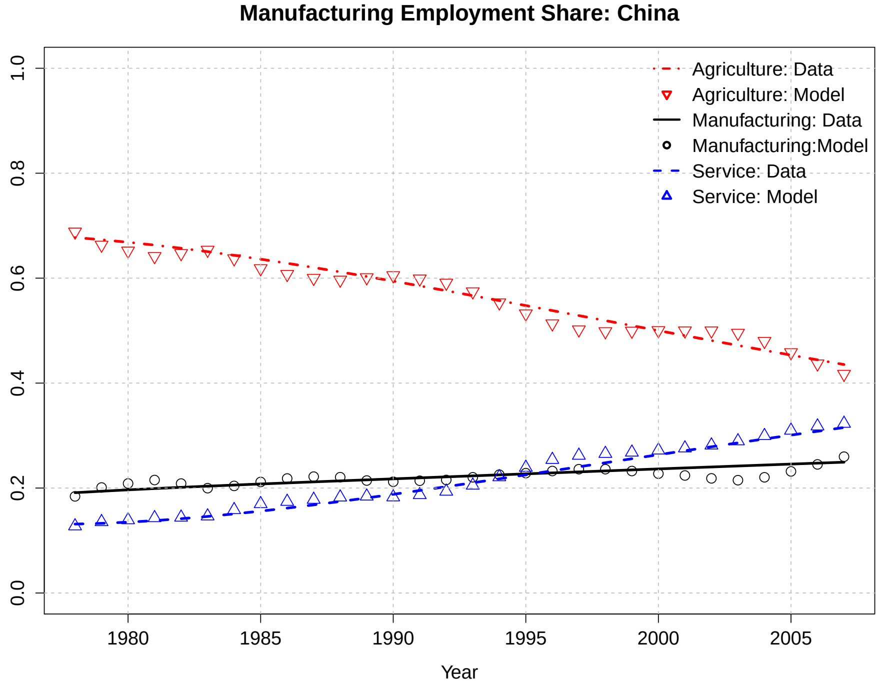

Figure 7: Employment share

is is highly possible that the investment rate will keep increasing, and the return to capital will not fall, and China's growth is sustainable.

4.3 The Case of Japan

I also use conduct similar calibration using the KLEMS data of Japan. Comparing to China, Japan displays a decreasing investment rate after 1970s and converge to its balanced browth path. This is due to the rapid increase of the service sector, the relative price of investment goods (manufacturing goods) declines rapidly. The investment rate generated by the model also shows an decreasing path.

5 Conclusion

This paper explores the role of structural change model in accounting for the dynamic pattern of aggregate investment rate. A three-sector general equilibrium model with Stone-Geary preferences and uneven TFP growth is build to establish a link between structural change and investment decisions. Only manufacturing goods can be invested. As a result, investment rate would show a similar transition path as manufacturing employment share and value added share. The intuition is as follows: 1) by separating consumption sector and capital

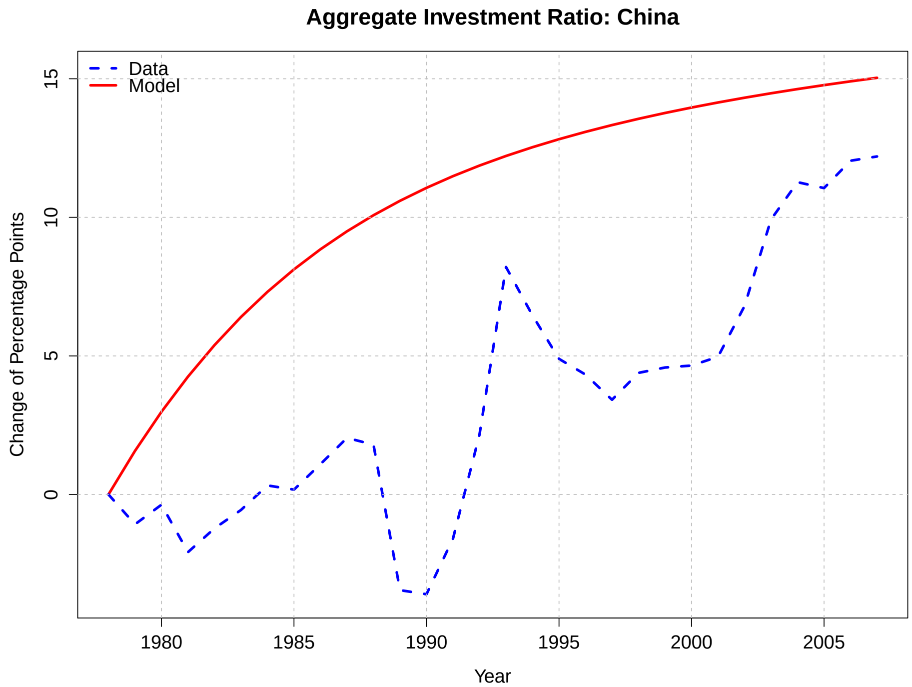

Figure 8: Aggregate Investment Rate: TFP Series with Constant Growth Rate

sector (with different production technologies and uneven TFP growth), the relative price of investment goods are decreasing over time, which results in an increasing investment rate at the beginning; 2) the introduction of Stone-Geary preferences also comes out with varying income elasticity and intertemporal elasticity of substitution over time, which can generate hump-shape investment rate.

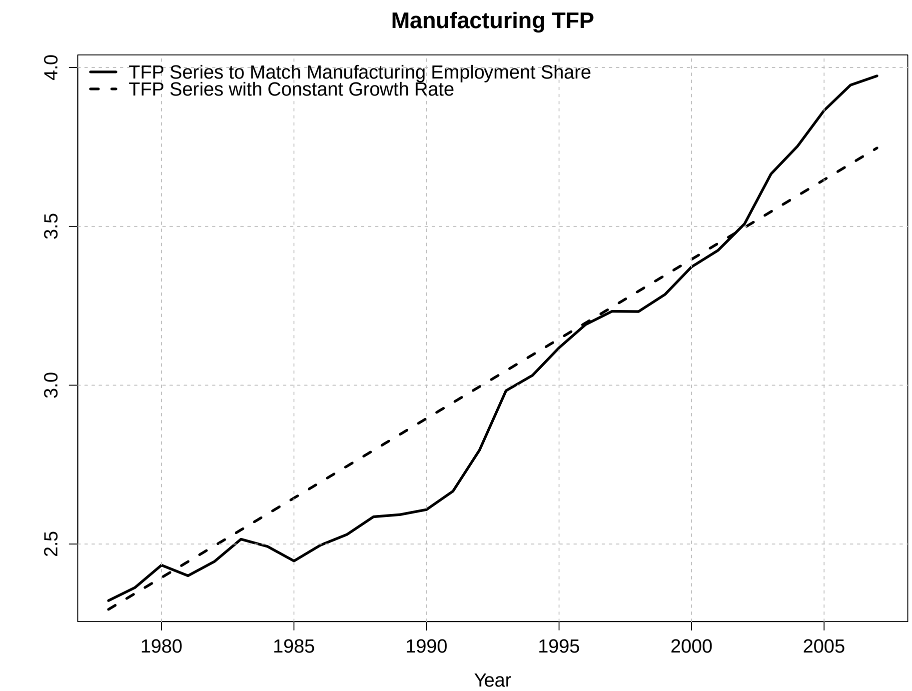

Figure 9: Calibrated Manufacturing TFP Series (log-scale)

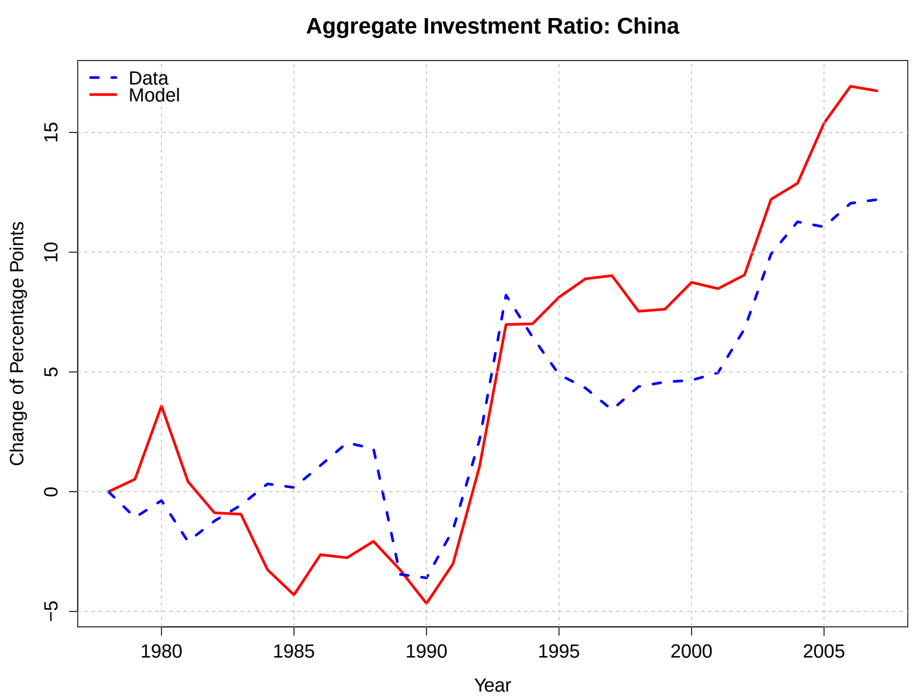

Figure 10: Aggregate Investment Rate: Calibrated Manufacturing TFP Series

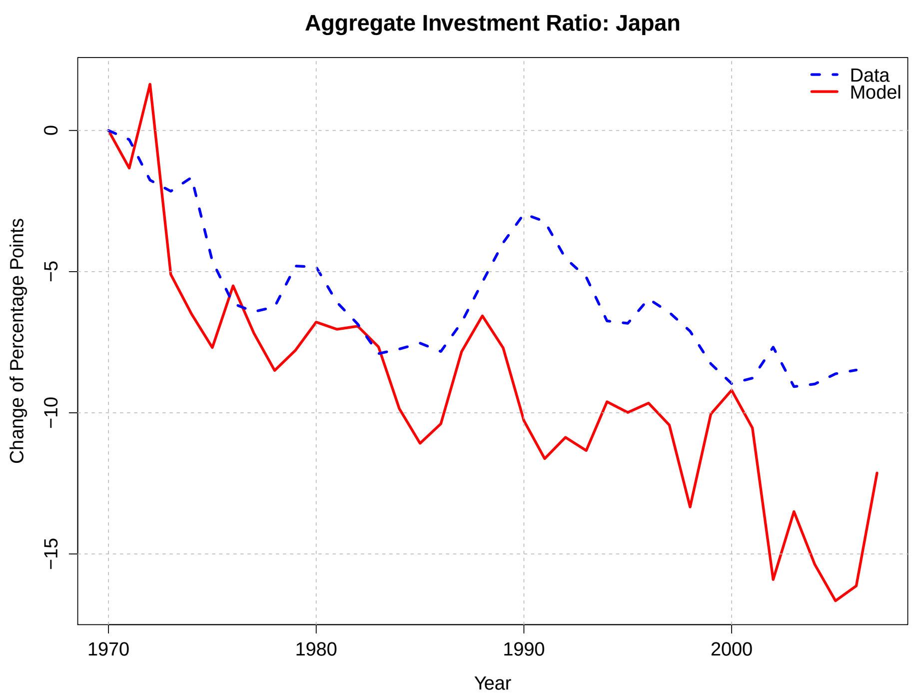

Figure 11: Aggregate Investment Rate: Japan

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A Data Description

A.1 China

A.1.1 Official Data

The aggregate economic time series, which include employment, value added, and capital by sector, are mainly collected from the *China Statistical Yearbook* (CSY) published by National Bureau of Statistics of China (NBS). The data ranges from 1978 (the year China started to reform) to 2007 (before the global financial crisis).[13]

Disaggregate level data of three sectors are needed. They are agriculture, manufacturing, and service. The agricultural sector consists of farming, animal husbandry, forest and fishing.[14] The manufacturing sector consists of mining, manufacturing, construction and public utility. The service sector consists of all the rest sectors.

Employment The official employment data has a structural break in 1990 after NBS modified its estimation based on 1990 Population Census. Therefore this break is quite artificial and it has been discussed by a few papers. To fix this jump, I followed the way used by Holz (2006) to adjust the data prior to 1990. The procedure is to adjust the aggregate employment using 1982 population cencus, and apply the sectoral shares before 1990 to the adjusted aggregate employment.

GDP Nominal aggregate and sectoral GDP data are collected from CSY 2013.[15] I use the implicit sectoral GDP deflator (collected from the same yearbook) to calculate the official constant price sectoral GDP. The base year is 1978.

Capital There is no official data for capital stock in China, hence I construct it with statistics of gross fixed capital formation (GFCF) reported by NBS.[16]

Nominal aggregate gross fixed capital formation data and implicit deflators are collected from official yearbooks. The more detailed fixed investment expernditure data are used to estimated sectoral gross fixed capital formation and they are scaled to be consistent with aggregate gross fixed capital formation. Then capital stock data for the 4 sectors are estimated using perpetual inventory method with the assumption that all sectors share the

[13] For the discussion on the issues of offical data, see Holz (2006); Wu (2011).

[14] The data contains agricultural service after 2002.

[15] The post-2004 GDP data have been adjusted according to the results of the second National Economic Census (2008).

[16] For potential problem of GFCF, see Wu (2011).

same capital depreciation rate $\delta = 0.05$:

$$K_j\,(t+1) = (1-\delta)K_j\,(t) + I_j\,(t)\,,$$

where I_j is gross fixed capital formation. The capital stock data of the first year for each sector are estimated:

$$K_j\,(1978) = \frac{I_j\,(1978)}{\bar{g}+\delta},\ j \in \{a, m, ds, ps\}\,,$$

where $\bar{g} = 0.1$ is the average output growth rate for 1978-1986.

B Model Discussion

B.1 The One-sector Model

B.1.1 The Standard Model

For benchmark purpose, we first show the investment rate generated by the standard one-sector growth model. From Figure 12 we can see that the investment rate generated by standard one-sector model is initially high, and then decreasing over time because of diminishing marginal return to capital.

B.1.2 The Model with Subsistence Requirement

Then we extend the stand one-sector model with subsistence requirement. The utility function is:

$$\max \sum \beta^t L_t \ln\left(\frac{C_t}{L_t} - \bar{a}\right),$$

s.t.

$$C_{nt} + X_t \leq w_t L_t + r_t K_t.$$

The production function in sector $i \in \{a, n\}$ is

$$Y_t = A_t K_t^{\theta} L_t^{1-\theta}.$$

Figure 13 shows the result. The model now can generate the increasing investment rate. This is because with the subsistence requirement, the elasticity of intertemporal substitution is ever-changing, and so is household's marginal propensity to save. Although we have

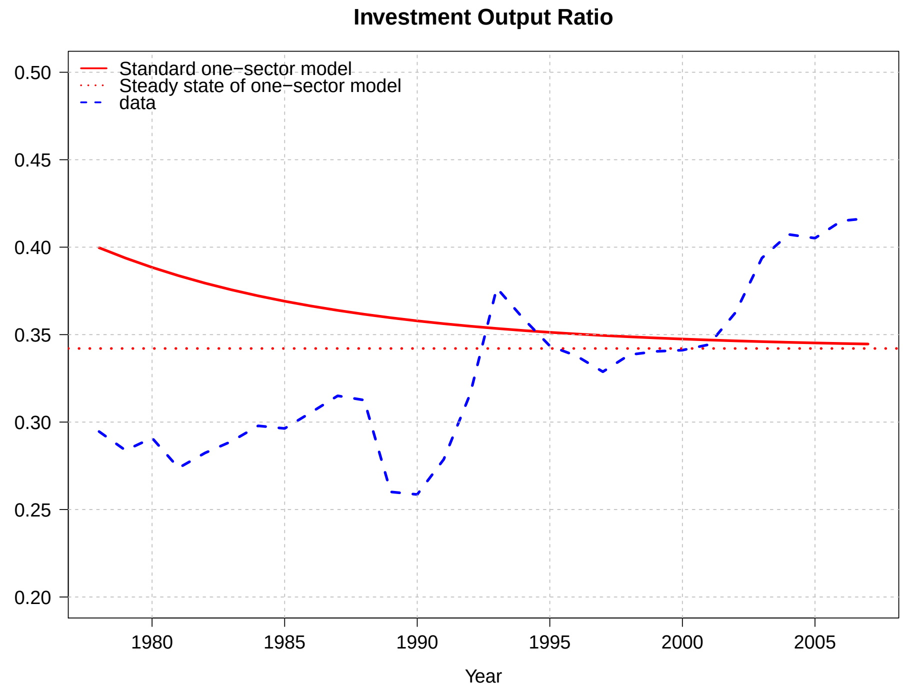

Figure 12: Investment Rate: Standard One-sector Model

increasing investment rate, there is still a large part is missing when comparing to the data: the overall range of investment rate change is too small, and the calibrated subsistence requirement to output $(\bar{a}/Y)$ is too large.

B.2 The Two-sector Model

Now we look at the two sector model. The utility function is:

$$\max \sum \beta^t L_t \left[\alpha \ln \left(\frac{C_{at}}{L_t} - \bar{a} \right) + (1-\alpha) \ln \frac{C_{nt}}{L_t} \right],$$

s.t.

$$p_{at} C_{at} + p_{nt} \left(C_{nt} + X_t \right) \leq \sum w_t L_t + r_t K_t.$$

The production function in sector $i \in \{a, n\}$ is

$$Y_{it} = A_{it} K_{it}^{\theta_i} L_{it}^{1-\theta_i}, i \in \{a, n\}.$$

First we calibrate the model with constant grow rate of sectoral TFP. Table 2 shows the calibrated parameter value. We can see that the calibrated model can well fit the sectoral employment rate (Figure 14), sectoral value added share (Figure 15), sectoral capital labor

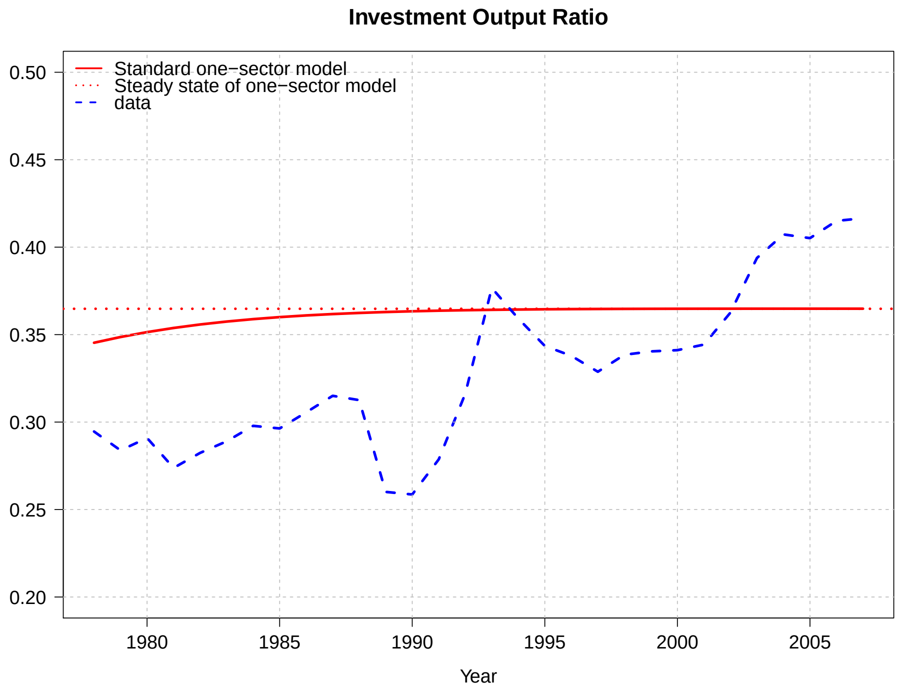

Figure 13: Investment Rate: One-sector Model with Subsistence Requirement

ratio (Figure 16-18), and sectoral labor productivity (Figure 19-20).

Table 2: Parameter Value for Two-sector Model

Parameter	Target
$\theta_a = 0.25$, $\theta_n = 0.54$	Cao&Bichenall(2013), Young(2003)
$\bar{a} = 1.161$	Initial value of L_a/L
$\gamma_a = 0.006$, $\gamma_n = 0.038$	Endpoints of L_a/L and average growth rate of Y_n/L_n
$\delta = 0.05$, $\beta = 0.97$	From the literature

Figure 21 shows the result of capital output ratio and investment output ratio. We can see that the model generated result can well cover the range of the data, and shows a stable capital return after 1985, which is consistent with the empirical evidence in the literature.

Figure 22 shows the result of aggregate investment rate. We can see the simulated results shows an increasing trend and can well cover the range of data. There are no fluctuations because we only assume constant TFP growth rate.

To see how well the two-sector model can do, we add TFP wedges (i.e., the TFP growth rate is not constant over time). Figure 23 shows the result. We can see the simulated result can well generate the sharp increase around 1990.

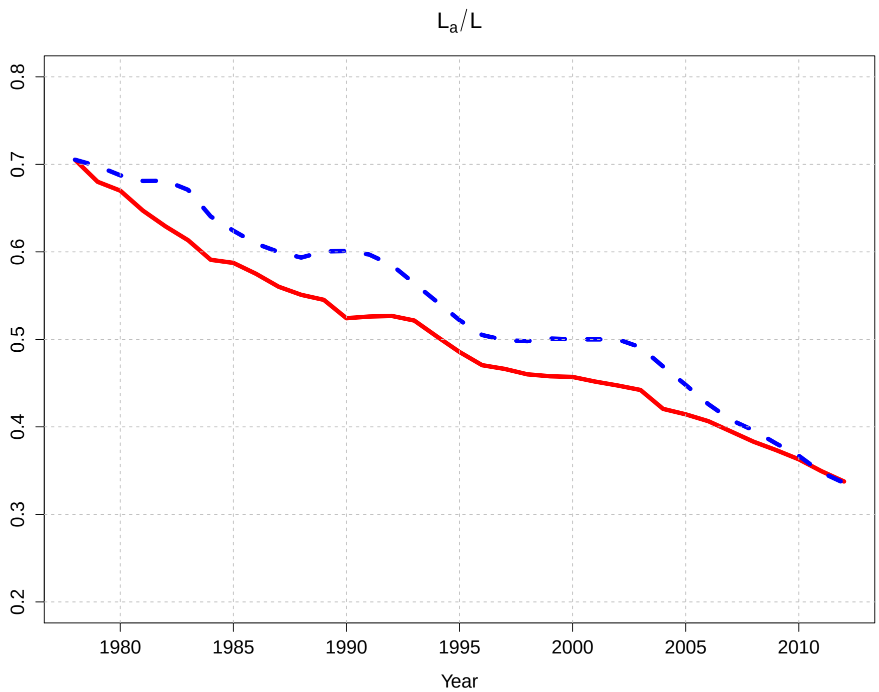

Figure 14: Calibration Result: Agricultural Employment Share

B.3 Other Factors

B.3.1 Foreign Direct Investment

This paper only considers a closed economy and all investment decision is endogenous generated by the domestic market. It is argued that foreign direct investment might also be an important driver for China's investment and economic growth. However, if we only look at the fixed capital formation data, the contribution from foreign investors are quite small.[17] Figure 24 compare the aggregate investment rate with and without FDI. We can see that the investment from FDI is at most 6 percent of GDP, and the FDI does not change the increasing trend of investment rate, which means the FDI is not an important determinant of investment rate in China.

B.3.2 Dependency Ratio

Until now only the change of employment is used in the calibration and it is assumed that employment and population have the same growth rate. It is argued that the change of population growth would also affect household's saving behavior, as well as the investment outcome. Figure 25 shows the dependency ratio (employment/population ratio) of China

[17] In fact, The FDI data also include wage and debt payment, which are not used for fixed capital formation.

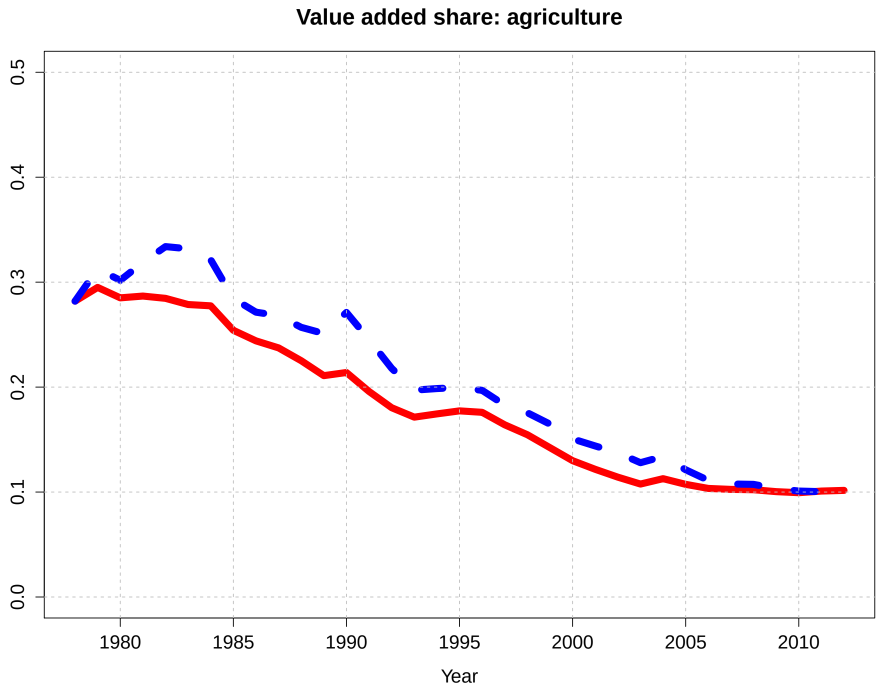

Figure 15: Calibration Result: Agricultural Value Added Share

from 1978 to 2012. We can see that during most of the time, this ratio is quite constant over time except for the initial period when China started to reform.

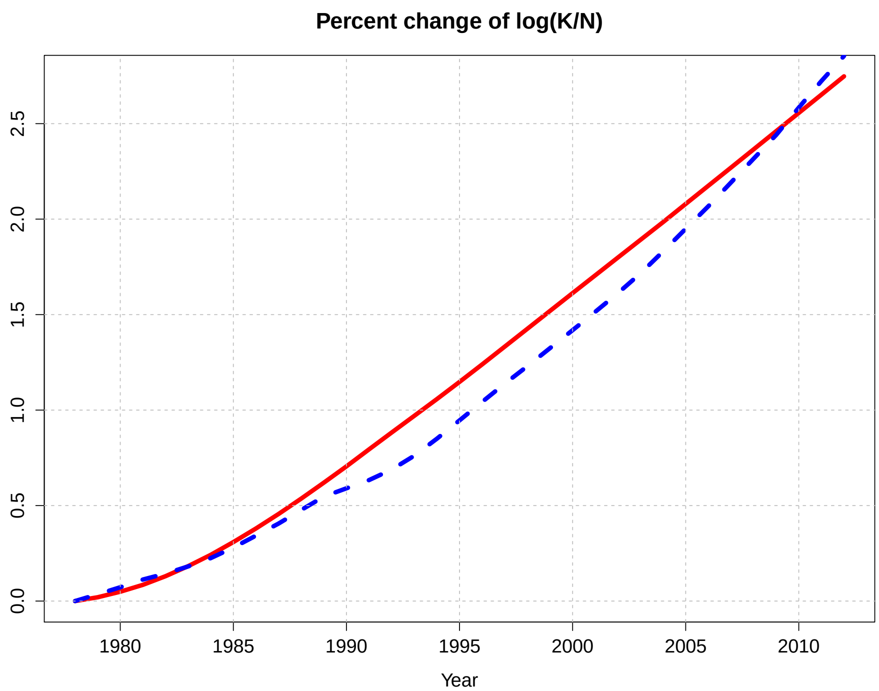

Figure 16: Calibration Result: Aggregate Capital-labor Ratio

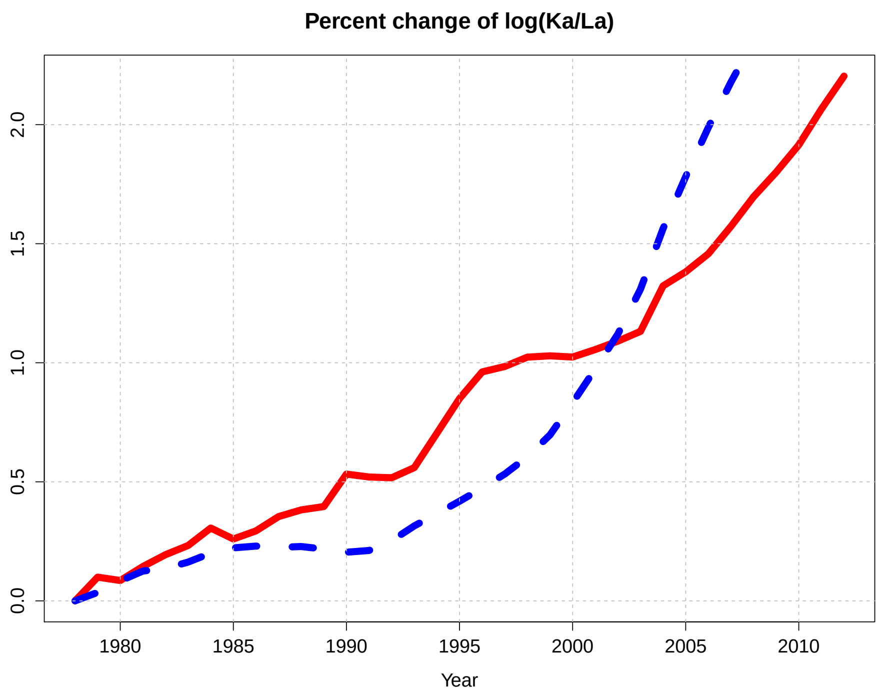

Figure 17: Calibration Result: Agricultural Capital-labor Ratio

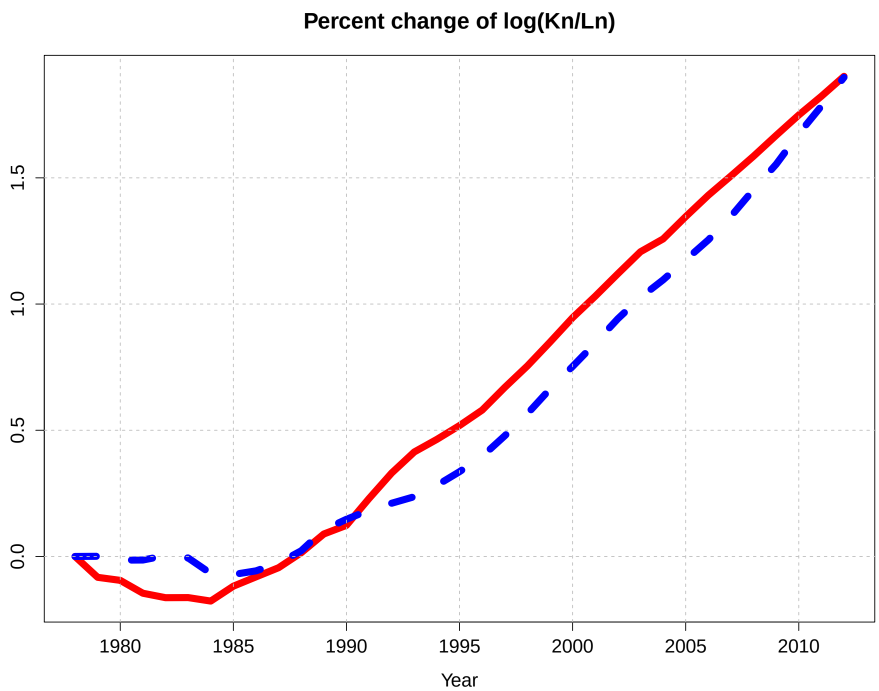

Figure 18: Calibration Result: Non-agricultural Capital-labor Ratio

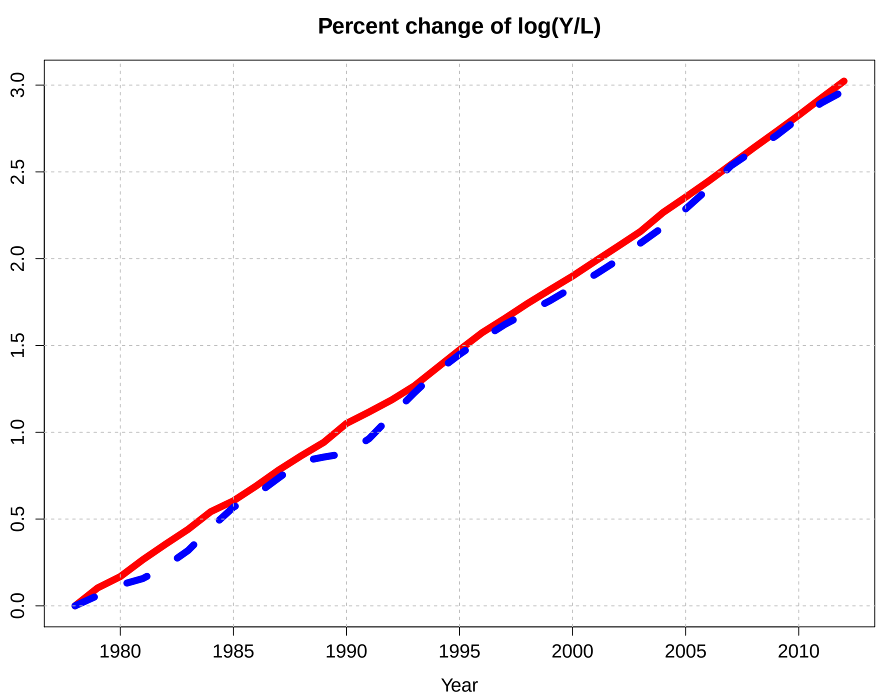

Figure 19: Calibration Result: Aggregate Labor Productivity

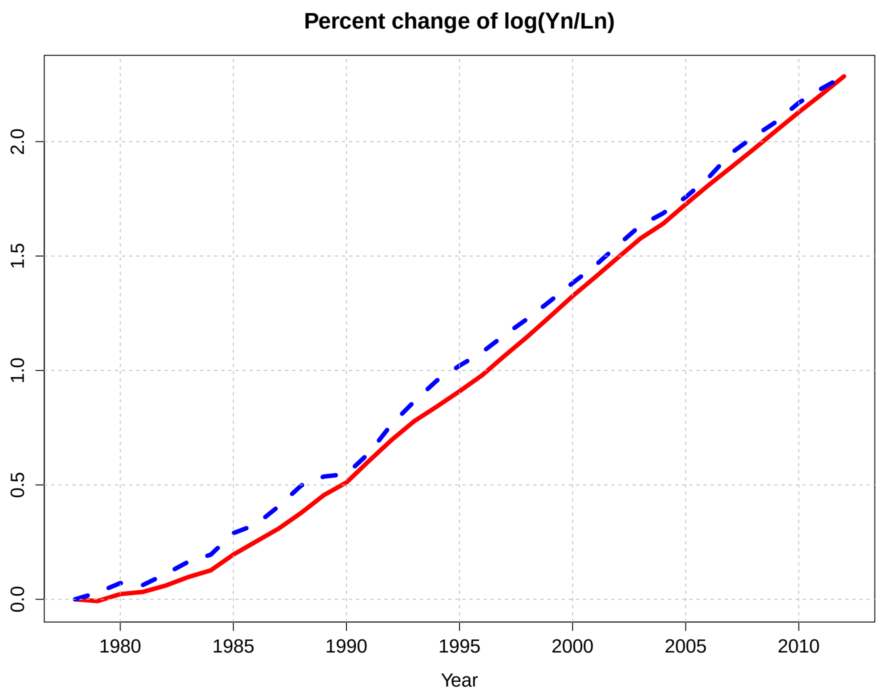

Figure 20: Calibration Result: Non-agricultural Labor Productivity

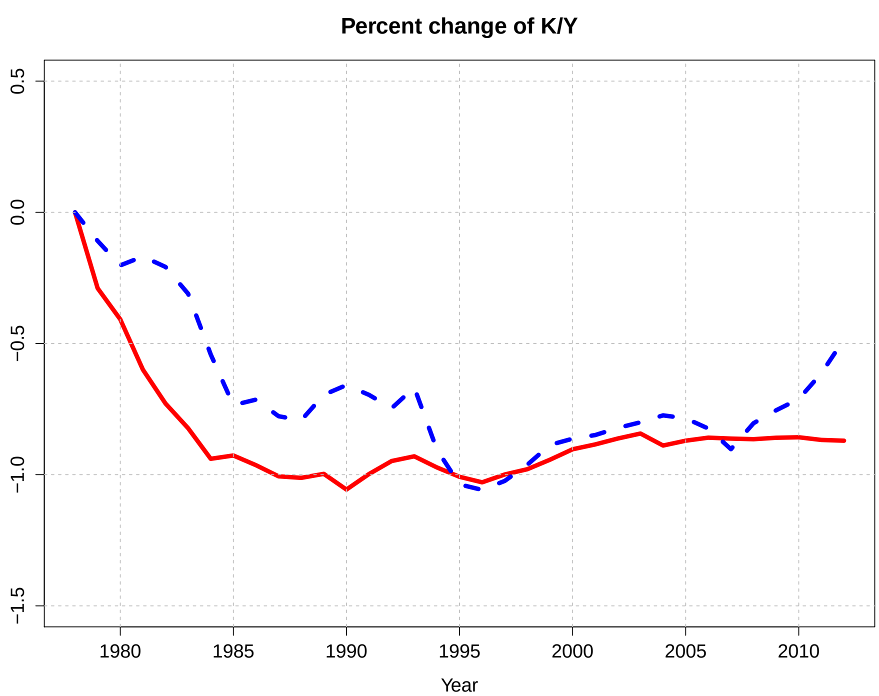

Figure 21: Calibration Result: Capital-output Ratio

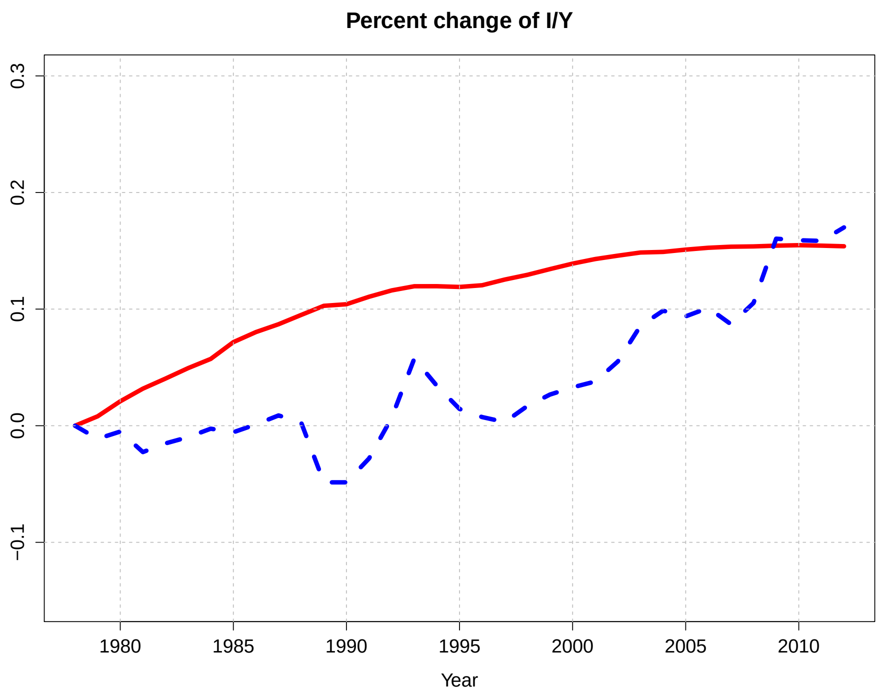

Figure 22: Calibration Result: Investment-output Ratio

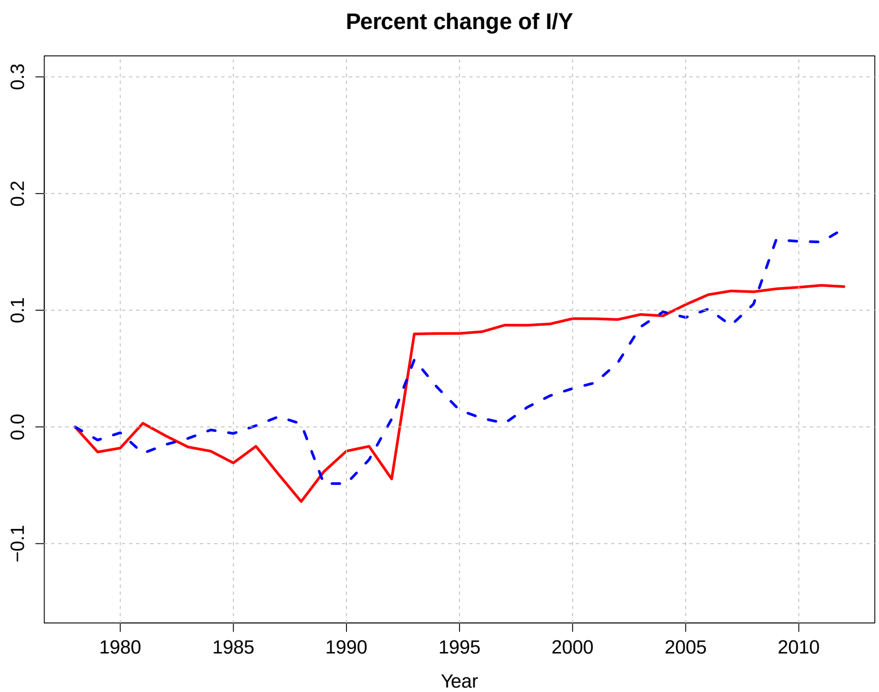

Figure 23: Calibration Result: Investment-output Ratio (with TFP Wedges)

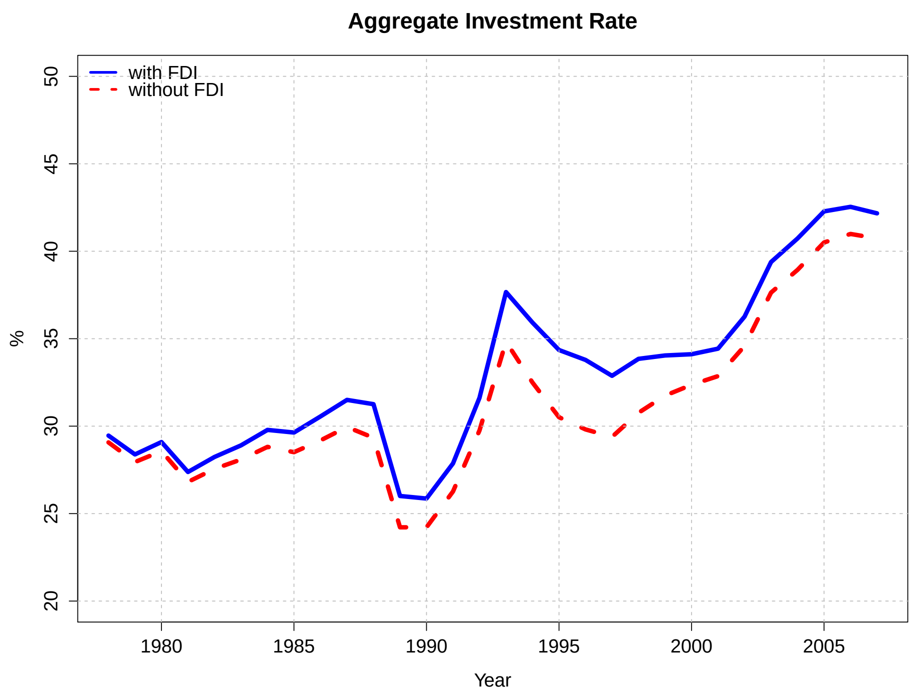

Figure 24: Aggregate Investment Rate without FDI

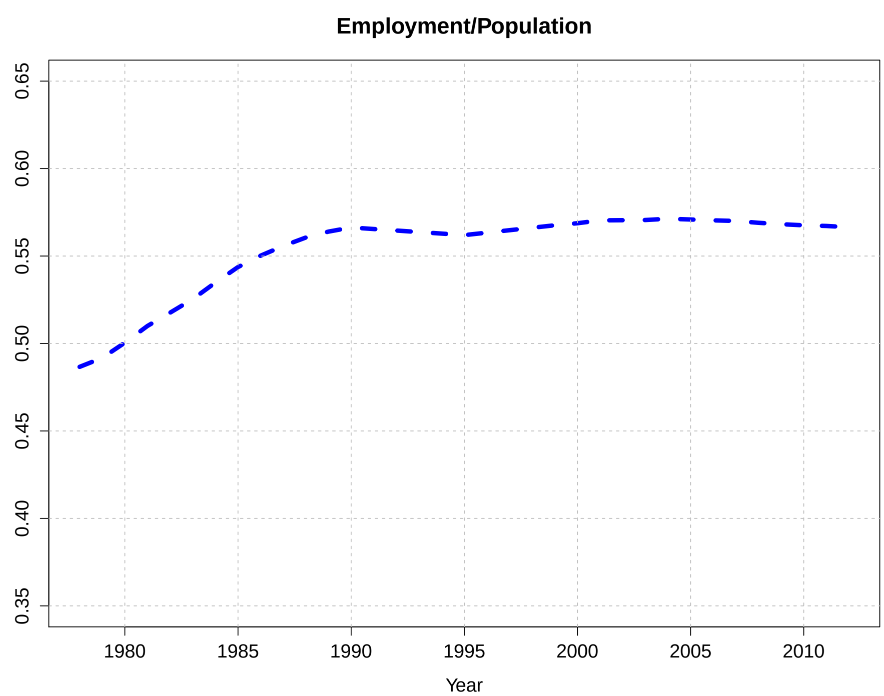

Figure 25: Dependency Ratio of China