Structural Change and the Sustainability of Chinese Economic Growth

(Preliminary Draft)

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Abstract

This paper examines the role of agriculture during the reform periods of China after 1978. I estimate the "shadow wage" of Chinese farmers from micro-level data and the result shows that the labor input of Chinese agriculture decreases at a rate of 2% annually. I combine this figure with the growth of output, capital, and land, and a growth accounting exercise demonstrates that the total factor productivity growth of agriculture is 5.4%. This number confirms the belief that the efficiency gain of Chinese economy during the reform periods mainly lies in agriculture. Then, I develop and calibrate a two-sector general equilibrium model with subsistent consumption, which sheds light on the sustainability of Chinese economic growth.

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1 Introduction

A country's economic development is characterized by the structural changes in production and employment, which is represented by a dramatic reallocation of resources between sectors and the decreasing shares of agriculture in total employment and production in an economy. Growth theory attributes these changes either to differences in income elasticity of demand or to differences in productivity growth between sectors. This paper combines both sides of the story. I develop a two-sector model of exogenous growth. I combine the sector difference in productivity and differences in the income elasticity of demand within a unified framework. I establish the steady state conditions for non-balanced economic growth, in which output in the two sectors grows at different rate despite the constant growth rate of capital and constant employment shares. The goal of this model is to capture the growth performance of a country and the transition of structural change. I calibrate the transition dynamic of the model and demonstrate how agricultural productivity affects the path of growth.

My model is mostly related to Matsuyama (1992) and Ngai and Pissarides (2007). Matsuyama (1992) shows that in a closed economy the employment share of agriculture is a decreasing function of agricultural productivity, given that the consumer has a Stone-Geary preference. The mechanism is subject to Engel's law: when the income elasticity of demand for food is less than one, which is implied by the Stone-Geary preference, people will spend smaller and smaller fractions of their income on food as the income increases over time. As agricultural productivity increases, labor becomes less and less demanded in the agricultural sector and is released to the industrial sector. Ngai and Pissarides (2007) focus on sectors have different productivity growth but have the same capital intensity. Unlike Matsuyama's (1992) model, preference remains homothetic: The outputs of each sector are produced according to a Cobb-Douglas production function, and the capital good is only produced by one of the sectors Ngai and Pissarides show that the aggregate economy in their model is consistent with the one-sector Ramsey model and their model exhibits structural change and an aggregate balanced growth. The employment converges to the sector with the lowest productivity growth.

Another contribution of my paper is to estimate the total factor productivity (TFP) of the agricultural sector. In particular, I apply my analysis to study the recent growth performance of China. Most of the existing literature approaches Chinese agriculture by examining aggregate data only because, as Young (2003) points out, in a less developed economy, large proportion of the income of an agricultural household comes from some sort of combined-factor rewards (land, capital, physical labor input, for example) of household production, rather than wage income. Consequently, there is no explicit observable individual "wage" paid to the labor that contributed to production. Without such information, we cannot correctly and fully quantify the contribution of labor input on agricultural productivity, and consequently the process and the pace of reallocation of labor between agriculture and non-agriculture[1].

I overcome this agricultural productivity problem by estimating the marginal productivity of agricultural labor, or "shadow wage", from micro farm-level data directly, which reflects the implicit reward in the decision making process made at the household level on how to allocate labor into agriculture and other activities. However, such estimates of marginal productivity of men and women are generally not much precise, because in terms of a household production, the allocation of labor within a family is endogenously decided and is affected by the usually unobservable factors, such as management skills, preference toward leisure, weather conditions, and so on[2]. Following Levinsohn and Petrin (2003), I use the level of intermediate input

[1]One way to alleviate this problem is assuming on the margin the return to agriculture workers is equal to the wage paid in the rural industry (Johnson and Chow 1997, Dekle and Vandenbroucke 2006). There is serious data limitation about this kind of approach. In order to absorb excess labor from agriculture, Chinese central government encourage local rural official to develop so-called Township and Village enterprises (TVEs), which are owned by the local rural citizens and operated by the local government. Right now TVE employs about 138 million people and is the largest labor force in China. Despite such huge success, it is hard to classify TVE as a market-orientated sector. Because of the fragmented labor market and official obstacles to both rural-urban and rural-rural migration, TVE contributes to a lot of its employment to localities. Due to the underdevelopment of financial institutions and the imperfect capital market, the local government does use its political connections with the central banks to channel loans to TVEs (See Byrd and Gelb (1991) and Chang and Wang (1994) for more details). Therefore, decision making process in TVE is not fully equivalent to a private-owned firm, and is highly subject to political influence. The wage rate in a TVE is not a good proxy for the marginal productivity of the Chinese peasants.

[2]To sign the bias, we need to know how the labor input relates to the error term. For example, if the share of women labor input increases within a season as the size of the output increases,

as a control for endogeneity problem, and I estimate the "shadow wages" of Chinese farmers, which are the weights for calculating agricultural labor input. My results shows that during the reform periods, Chinese agricultural labor input decreased at a rate of 2% annually, and that agricultural productivity growth was on an average of 5.4%, which is more than three times higher than Young (2003) estimate for the non-agricultural sector.

The rest of the paper is organized as follows. Section II presents the model and discusses the theoretical results. Section III presents the estimation methodology for agricultural TFP growth. Section IV calibrates the model and demonstrates the transition dynamic. Section V concludes.

2 Related Literature

Much of the recent Chinese economic growth starts with the agricultural sector, as shown by what many other countries have achieved. The rural area of China was most severely affected by the central planning system, which models the former Soviet Union's highly centralized and heavy-industry orientated development framework. Capital was mainly accumulated and concentrated in the infrastructure sector without enough economic variety and employment opportunity. Chinese farmers bore most of the finance burden, through the "unified purchase and sale system" that maintained a scissors' difference between agricultural and industrial prices. Farm products were purchased at a mandatory low price by the state and sold to urban area and industrial firms at a similarly low price, so that the production cost in the heavy industry was minimized. It is estimated that, by maintaining the price scissors for almost 30 year, the rural population indirectly paid over 800 billion yuan in taxes since the early 1950s (Wu 1994).

In 1978, the first reform was implemented right in the country side, upon the

because women are called for help only when the harvest are plentiful. In such case the female labor is positively correlated to the errors (as production shock), and further more if this correlation is higher than male's correlation, the OLS estimate of female's marginal productivity would tend to be biased upward and the male's coefficient is underestimated, given other factors being constant.

danger that farmers in poor regions would bring down the whole country. Lin (1992) has documented such reforms in detail. The collective commune system was replaced by the household responsibility system (HRS). Under the old system, people in the rural area were put together into a production team, and by law all the land and machinery were owned by the team not by individuals. The work in the field was assigned to each team member. Ideally individual income should depend on one's contribution to the production. However, because it was almost impossible to monitor how effective each individual's work was, the total income of a production team was either divided equally among the members or determined by the team leader subjectively. Thus, the link between individual effort and compensation was broken. McMillan et al. (1989) estimate that in the commune system an individual worker would be paid as low as 30 percent of his or her marginal value of the product. Under HRS, state-owned land was assigned to each household with contracts up to 15 years, and for the first time an individual became the primary unit for decision making. "Once a peasant's state quota and collective contribution have been fulfilled, the rest is his to dispose of as he wishes." This slogan advertised from the government officials captured the main spirit of the reform: a reward to each own marginal effort and the accommodation of the interests of the state, collective, and individual. The effect of the agricultural reform has been phenomenal. China's crop output increased by 42 percent during 1978-1984. Lin (1992) shows that HRS heavily accounted for about half of such growth. Not surprisingly, after HRS was widely spread throughout the whole country, agricultural growth slowed down.

For the overall economy, China has maintained unprecedented achievements in terms of output growth for almost thirty years since 1978. This type of performance has caused scholars to cast doubt on the credibility of the Chinese official data. However, Young (2003) takes a different approach, accepting those official data and making adjustment wherever appropriate. Meanwhile, Young focuses on the non-agricultural sector only, because the data and technique of studying agricultural problems are unique and not applicable here. First, Young (2003) finds out that the most serious problem associated with the Chinese official data is the implicit GDP deflator, which relies on enterprise-reported data and systematically underestimates the inflation. Therefore, independent price indices should replace the implicit GDP deflators for different sectors. After such adjustments, the annual growth rate of output in the non-agriculture sector is reduced by 2.5 percent. Second, Young (2003) shows the growth rate of labor forces exceeded population growth, which was lead by the rising female participation rates. Improvements in education increased the quality of labor at the rate of 1.1 percent per year during the reform period. Combining both factors accounts for 37 percent of the output growth. The productivity of the non-agricultural sector grew at 1.4 percent, not an outstanding performance. Therefore, Young (2003) concludes, "[t]o the degree that the reforms have improved efficiency, these gains may lie principally in agriculture."

3 Model

In this paper, I develop a two-sector growth model, based on Ngai and Pissarides (2007), but I combine non-homothetic preference and exogenous productivity growth together. A representative agent has the standard preference of two goods:

$$U = \int_0^\infty u(c_a, c_m) e^{-(\rho - v)t} dt, \tag{1}$$

where c_a and c_m are per capita consumption of the agricultural good and the manufacturing good, ρ is the rate of time preferences, and v is the growth rate of the labor force. The instantaneous utility function takes the Stone-Geary form:

$$u(c_a, c_m) = \phi \ln(c_a - \gamma) + (1 - \phi) \ln c_m, \quad \textit{where } 1 > \phi > 0 \ \textit{and } \gamma > 0.$$

γ can be interpreted as the minimum food consumption for an agent and it captures the effect of Engel's law. This is a key feature to establish a link between agricultural productivity growth and the overall performance of the economy.

The agricultural sector only produces consumption good, whereas the output from the manufacturing sector can be either consumed or invested. Both sectors are equipped with a constant return to scale, Cobb-Douglas technologies. Therefore:

$$c_a = A_a k_a^{\alpha_a} n_a \tag{2}$$

$$\dot{k} \;=\; A_m k_m^{\alpha_m} n_m - c_m - (\delta + v)k, \tag{3}$$

where $\delta > 0$ is the depreciation rate, k_i is the capital-labor ratio in sector i, n_i is the employment share and

$$n_a + n_m = 1. \tag{4}$$

k is the aggregate capital-labor ratio and it must satisfies

$$k = n_a k_a + n_m k_m. \tag{5}$$

The parameters $\alpha_i \in (0,1), i = a, m$, determine the capital share in production. Technological progress in the two sectors are exogenous and are at different rates: $\dot{A}_i / \; A_i = \mu_i$, $i = a, m$. The difference of TFP growth in two sectors allows the model to accommodate my empirical finding that Chinese agricultural productivity growth is higher than the non-agricultural growth during the reform period.

3.1 The Transitional Path

A social planner chooses the sequences $\{c_a, c_{m,} k_a, k_m, n_a\}_{t>0}$ so as to maximize the lifetime utility of the representative consumer subject to the feasibility constraints of the economy, and the initial values. The problem is stated as follows:

$$\max U = \int_0^\infty [\phi \ln(c_a - \gamma) + (1-\phi)\ln c_m] e^{-(\rho - v)t} dt,$$

subject to (2) to (5), together with the initial conditions k_0.

The optimal consumption path of manufacturing goods is according to the following Euler equation:

$$\frac{\dot{c_m}}{c_m} = A_m \alpha_m k_m^{\alpha_m - 1} - (\delta + \rho + v). \tag{6}$$

Given the Cobb-Douglas production function, the capital and labor across sectors are chosen efficiently by:

$$k_a = B \cdot k_m, \quad where\ B = \frac{\alpha_a(1-\alpha_m)}{\alpha_m(1-\alpha_a)}. \tag{7}$$

For a given set of α_i, the capital to labor ratio in every sector is proportional to each other. Since the aggregate capital-labor ratio is $k = n_a k_a + n_m k_m$, equation (7) also implies

$$k = (n_a \cdot B + n_m) k_m. \tag{8}$$

In a decentralized economy, let p be the relative price of the agricultural good:

$$p = \frac{A_m}{A_a} \cdot D \cdot k_m^{\alpha_m - \alpha_a}, \quad where\ D = \left(\frac{\alpha_m}{\alpha_a}\right)^{\alpha_a} \left(\frac{1-\alpha_m}{1-\alpha_a}\right)^{1-\alpha_a}, \tag{9}$$

and

$$\frac{\phi}{1-\phi} \frac{c_m}{c_a - \gamma} = p. \tag{10}$$

Therefore, combining the budget constraint of the aggregate resource, the profit maximization conditions in each production sector, and the solution to the consumer's intertemporal problem, the solution to the social planner's problem (SP) can be characterized as two dynamic equations, (3) and (6), and four static equations, (2), (8),(9) and (10).

This model has some insightful results which place the agricultural TFP growth at the key of the model. First, according to equation (9), the change of the relative price is:

$$\frac{\dot{p}}{p} = \mu_m - \mu_a + (\alpha_m - \alpha_a) \frac{\dot{k}_m}{k_m}. \tag{11}$$

In an economy that k_m is growing over time, the fall of the agricultural price can be attributed to a higher TFP growth and a higher capital share in agriculture[3]. More important, when the preference is homothetic, i.e., $\gamma = 0$, the model can be fully characterized without the role of the agricultural productivity. To see that when

[3]Ngai and Pissarides (2007) draws a similar results.

$\gamma = 0$, substituting equations (2) and (9) into equation (10) and cancelling common terms give us:

$$c_m = E \cdot A_m k_m^{a_m} n_{a,} \quad where \;\; E = \frac{1-\phi}{\phi}\frac{1-\alpha_m}{1-\alpha_a}.$$

All the terms associated with agricultural productivity are cancelled during the process above. This solution to this model reduces to the following four equations:

$$\frac{\dot{c_m}}{c_m} = A_m \alpha_m k_m^{\alpha_m - 1} - (\delta + \rho + v), \tag{12}$$

$$\dot{k} \;=\; A_m k_m^{\alpha_m}(1-n_a) - c_m - (\delta + v)k, \tag{13}$$

$$k = [(B-1)n_a + 1]k_m, \tag{14}$$

$$c_m = E \cdot A_m k_m^{a_m} n_a. \tag{15}$$

Therefore, when this economy is growing over time and γ plays a less and less important role in determining the equilibrium, I assume that in the long run the system (SP) converges to (12)-(15), an asymptotic growth path that consumption and capital of manufacturing goods are growing at the same rate and the employment share of agriculture remains constant without the influence of γ. The growth is non-balanced because outputs in the two sectors grow at different rates. A positive γ is only effective during the transition, in which sectors' capital stock and production depend on the agricultural productivity through the link of a positive γ. I solve the transition path numerically to further investigate the significance of such interdependence.

3.2 Steady State Growth

In order to solve the transitional path, I normalize the consumption of manufacturing good and the capital good in terms of the growth rate of labor-augmenting technology: $\widehat{k} = kA_m^{-1/(1-\alpha_m)}$, $\widehat{k}_m = k_m A_m^{-1/(1-\alpha_m)}$,and $\widehat{c}_m = c_m A_m^{-1/(1-\alpha_m)}$. Let

$g_m = \frac{\mu_m}{1-\alpha_m}$.The dynamic equilibrium conditions become:

$$\frac{\dot{\widehat{c}_m}}{\widehat{c}_m} = \alpha_m \ \widehat{k}_m^{\alpha_m - 1} - (\delta + \rho + v - g_m) \tag{16}$$

$$\dot{\widehat{k}} \ = \ \widehat{k}_m^{\alpha_m}(1 - n_a) - \widehat{c}_m - (\delta + v + g_m)\widehat{k} \tag{17}$$

A steady state is that the normalized items grow at a rate of zero and the share of agricultural workers is constant. Therefore, I can obtain the steady state value of $\widehat{k}_m$, $\widehat{c}_m$, and na by setting equation (16) and (17) to zero. Let a start denotes the "steady state" value, we have:

$$\widehat{k}_m^* = [\frac{1}{\alpha_m}(\delta + \rho + v + g_m)]^{\frac{1}{\alpha_m - 1}}$$

$$n_a^* = \frac{\widehat{k}_m^{*\ \alpha_m} - \widehat{k}_m^*(\delta + v + g_m)}{\widehat{k}_m^{*\ \alpha_m}(1 + E) + \widehat{k}_m^*(\delta + v + g_m)(B - 1)}$$

$\widehat{c}_m^*$ and $\widehat{k}^*$ follow trivially from equations (14) and (15). These steady state values are important for identifying the transition path of the model.

To solve the model, first I realize that in steady state, the aggregate and manufacturing capital-labor share, k and km, are growing at the same rate given by the equation (14). This allows me to rewrite equation (17) into:

$$\dot{\widehat{k}}_m \ = \ \frac{(1 - n_a^*)}{(B - 1)n_a^* + 1}\widehat{k}_m^{\alpha_m} - \widehat{c}_m - (\delta + v + g_m)\widehat{k}_m \tag{18}$$

Therefore, equation (16) and equation (18) are two differential equations which line up with the equilibrium conditions of the Ramsey model, and I solve them by linearazing about the steady state values. Once I find the saddle-path solution of $(\widehat{c}_m, \widehat{k}_m)$, the static conditions, (8) to (10), give us the evolution of n_a and k.

4 Measurement

For the purpose of this paper, I need two important inputs of my model: agricultural and manufacturing sector TFP growth of China. Since the reform started in 1978, China has transformed from an agrarian and central-planned society into an industrialized and market-orientated economy. The number of people who engaged primarily in agricultural activities has declined from 70 percent of the total employment in 1978 to 50 percent right now. The share of agricultural output also has followed a similar track, and has reduced from 28 percent to 14 percent (see Figure 1 and 2). Young (2003) concludes that the performance of non-agricultural productivity in China during the reform period of 1978 to 1998 was not that outstanding and the TFP in the manufacturing sector grows at a rate of 1.4% per year since the late 70s. I

However, Young (2003) does not go any further to investigate the agricultural sector, because that requires a totally different method. To see this, let's assume the total labor input can be viewed as a constant return to scale function H with N types of labor: $L = H(L_1, L_2, ..., L_N)$. Each type of labor could be different with the age, gender, or educational background, so each type of labor has its specific marginal productivity. The overall labor index can not be as simple as adding numbers of workers together. The growth of aggregate labor should be computed by summing of the change in each type of labor, weighted by its marginal productivity or its share in total outlay under the assumption of competitive market:

$$\begin{aligned} \frac{d\ln L}{dt} &= \sum_{i=1}^{N} v_i \frac{d\ln H_i}{dt}, \\ \text{and } v_i &= \frac{w_i H_i}{wL}, wL = \sum_{i=1}^{N} w_i H_i. \end{aligned} \tag{19}$$

where w_i, the productivity of type i, empirically is reflected by the compensation paid to labor from a producer's point of view, i.e. the wage level observed in the job market. However, for the agriculture sector of a developing country, there is not observable wage.

This paper improves upon Young (2003) in the agricultural labor-input problem by estimating the marginal productivity of agricultural labor or the "shadow wage" from a micro farm-level survey data directly, in terms of a Cobb-Douglas production function framework. The implicit reward in the decisions making process made at household level on how to allocate labor into agriculture and other activities can be reflected from such estimation. To estimate the marginal productivity of labor in the Chinese farms, let's assume a Cobb-Douglas production function which is specified as:

$$\ln Y = \sum_i \beta_i \ln L_i + u,$$

where Y is the total value of output related to household production. L_i is various types of inputs, and u is an error term. Based on the estimation result, the shadow wage of labor input type i can be calculated as the following equations:

$$w_i = \exp(\widehat{\beta}_i), \tag{20}$$

where $\widehat{\beta}_i$ is the coefficient on $\ln L_i$ and $\widehat{Y}$ is predicted value of output[4]. An estimation of the above kind suffers greatly by the endogeneity problem[5]. In this paper I follow the practice of Levinsohn and Petrin (2003) and use the intermediate input as a proxy to control for the common endogeneity problem in production function estimations.

[4]See Jacoby (1993) and Skoufias (1994) for a similar approach.

[5]This endogeneity problem in estimating a production function has a long history in economics studies, but unfortunately there is not unique universal-satisfied solution for this problem. One approach is to assume the unobserved variables in the production to be a time-persisting agent-specific effect. But this fixed effects estimator needs a strict exogeneity assumption of the inputs (Wooldrige 2002), which implies inputs cannot respond to the productivity shock. Therefore fixed effects model cannot fully resolve the problem and is not suitable to be used here. Instrumental variables estimation is often used as another possible solution, which requires a proxy that correlated with the dependent variable, but uncorrelated with the error term. One candidate for such instrument is the input price along with the assumption that there exists a competitive input market. However, input prices often have not enough variation across households, and in the case of agriculture household the price of labor input is not even observed! Characteristics of a household, such as number of children, generally are not good for an instrument, since household composition do reflect the life-long decision on how to allocate time and resource for a family.

4.1 Labor Input

This study uses the longitudinal data from the China Health and Nutrition Survey (CHNS), conducted by the Carolina Population Center, the University of North Carolina at Chapel Hill. An advantage of this survey is that it allows us know who does what in the farm. This information is important for estimating the shadow wage because of the complexity of agricultural household production. The analysis here is restricted to production and time allocation data from the sample rural area of the calendar years 1993 to 2004 and for total households of 9539 with 29850 individuals. Table 1 contains summary statistics of some key variables.

I cross-classify the labor input into three factors: sex (s), age (a) and education (e), where

$$\begin{aligned} \text{s} &= \text{male and female} \\ \text{e} &= \text{under primary, primary, secondary, and tertiary}^{6} \\ \text{a} &= \text{under 20, 20-24, 25-29, 30-34, 35-39, 40-44,} \\ &\quad \text{45-49, 50-54, 55-59, 60-64, and over 65 years old.} \end{aligned}$$

Therefore, I distinguish the labor input into 88 ($2 \times 4 \times 11$) categories. To obtain the marginal productivity of each type of inputs, I estimate the following production function by OLS:

$$\ln Y_t = \beta_0 + \sum_{l=1}^{88} \beta_l \ln L_{lt} + \sum_{i=0}^{3} \sum_{j=0}^{3-i} \delta_{ij} \ln C_t^i \ln A_t^j + \varepsilon_t \tag{21}$$

where Y_t is a household's total output at time t, L_{lt} is the number of hours work at time t for labor type l, C_t is total expenditure of intermediate inputs, and A_t is the land[7]. Table 2 summarizes the regression results of (21). Note that only the coefficients on the labor input, $\widehat{\beta}_l$, are consistently estimated, so I only report those estimates. Based on such estimates, the marginal productivity (or shadow wage) of

[7] To avoid presence of log zero, a constant equal to one is added to all the input variables except land.

each individual from the sample were derived using the equation (20).

Equation (19) defines the growth rate of a Divisia index of labor input. Since economic data is at a discrete time format and the index above is defined in continuous time, the discrete approximation of equation (19) is given by:

$$\Delta \ln L = \sum_{i=1}^{N} \overline{v}_i \Delta \ln H_i, \tag{22}$$

where there are N types of labor ($N = 88$ in our case), H_i is the hours worked for type i, $\overline{v}_i = \frac{1}{2}(v_{i,t} + v_{i,t-1})$ with $v_{i,t}$ is the labor i's share in total outlay at time t, and the Δ denotes the first differences associated with time, for example, $\Delta \ln L = \ln L_t - \ln L_{t-1}$. Thus, the growth rate of labor input is the sum of the change in the log of labor i's hours worked weighted by its average shares in the aggregate labor compensation. Define the unweighted sum of total hours worked, H_t, as $H_t = \sum_i H_{i,t}$. Then, I can define the quality of labor Q_t, by $L_t = Q_t H_t$. It gives us the growth rate of the quality of labor:

$$\Delta \ln Q = \Delta \ln L - \Delta \ln H.$$

After substituting in equation (22), a couple more steps of algebra shows the following:

$$\Delta \ln Q = \sum_{i=1}^{N} \overline{v}_i \Delta \ln d_i$$

where $d_{i,t} = H_{i,t}/H_t$, is the proportion of hours worked by the ith type labor. This indicates that the growth rate of the quality of labor, $\Delta \ln Q$, measures the changes in the composition of hours worked by sex, age and education.

To compute the growth rates defined above, I need to compile the data on hours worked and labor compensation. The latter is based on the estimated shadow wage. The predicted wage for each type of labor is obtained by regressing the shadow wage on categorical dummies. Then, I use a similar regression method to get average hours worked for each type of labor, since the survey data contain detailed information about each person's annual work hours. Finally, the employment for each category is calculated by multiplying the categorical distribution of the labor force from the survey (summarized in Table 3) and aggregate agricultural employment data from the *China Statistical Yearbook* (CSY).

Table 4 presents the main results of this analysis. As should be expected, the labor input in agriculture is decreasing at a rate of 1.99 percent annually in an accelerating pace as the economy grows. In the contrast, Young (2003) shows the growth rate of labor input in Chinese nonagricultural sector between 1978 and 1998 is about 2.6 percent per year. This indicates that the structure change, transferring labor from agriculture to industrial sectors, is the main feature of Chinese development during the reform period. Before entering the 21st century, the quality of labor on average is increasing at a rate of 1.5 percent per annum, which is similar to Young's (2003) estimate for nonagricultural workers during the period of 1978 to 1998 (1.1 percent per annum). However, such improvement slows down after 2000. My estimate shows the quality of labor actually decreases by about 3.5 percent each year from 2000 to 2004. This is probably due to the ageing population in the rural area of China, since usually it is the younger generation who migrates to the city. The distribution of working population also exhibits this trend. In 2004 only 13 percent of the workers in agriculture are under 30 years old, while the number in 1993 was almost 30 percent. Comparing the results to the Japanese and the U.S. data, we can see that in terms of reducing agricultural labor input, China is performing as well as what Japan and the U.S. accomplished in the past. All three countries were managed to cut down the labor input for agriculture at a peace of more than 3 percent annually.

4.2 Total Factor Productivity Growth

To complete my study of TFP growth, I need some aggregate measures of Chinese agricultural output, capital and land. Despite the fact that many researchers remain skeptical about how accurate the Chinese official statistics are (e.g., Rawski 2001), I embrace the official data with a belief that Chinese data are reliable in general and are constructed by Chinese officers with the best knowledge available[8]. The data for aggregate measures of agricultural output, capital, labor, and land are mostly taken from the China Statistical Yearbook (CSY) with necessary adjustments. First, according to Young (2003), the official GDP deflator is inadequate and underestimates the inflation during the reform period. Young (2003) suggests using alternative official price indices to construct the real GDP series. Hence, I follow Young's approach and deflate the nominal GDP in agriculture, industry, and service sectors by purchasing price index for farm products, ex-factory price index of industrial products, and consumer price index (services), respectively. These constructed data show that the agricultural output grew at 5.6 percent on average from 1978 to 2003.[9] Second, because the CSY only contains one measure of national capital stock and does not break down the capital into different categories by sectors that we need, my measurement of agricultural capital stock relies on the estimates by Dekle and Vandenbroucke (2006)[10]. They aggregate the provincial data, which do decompose the capital into three sectors, into one national measure that shows the growth rate of Chinese agricultural capital is 3.1 percent annually. Third, labor is measured by the number of persons who engaged in working activities and received some sort of income in each calendar year. The employment data from the CYS shows that after 1978 the number of people engaged in agriculture has increased about 1.1 percent annually, which is much less than Young's (2003) estimates for the whole country (2.2%) and for the industrial sector (4.5%)—an indicator of structural change. Last, the input of land in the agricultural sector is measured by the total crops sown area, and this

[8] After entering this century, China began to adapt the new national account system (NAS) to replace its old system of material product balances (MPS) adopted by the former Soviet Union. The MPS was created to fit the need of the planned economic economy, which emphasized the activity of producing and distributing of material products. One of the most serious drawbacks of the MPS was the lack of complete accounting for activity in the service sector. The MPS only accounted for the material production and the services related to this material production. The consequence of this type of system greatly hindered the development of the service sector in the socialist economy. As China adapts more and more to the worldwide NAS, China has to face its big problem: the lack of service sector calculation. For example, in the 2002 CSY the GDP for the service sector in 2001 was 3,235 billion yuan, but in the 2003 CSY this number changed to 3,315 billion.

[9] The growth rate in this paper is ln growth rate.

[10] The data is available online at http://www-rcf.usc.edu/~vandenbr/China-Data.xls.

figure does not vary much over time with an annual growth rate of 0.3 percent.

4.2.1 Factor Shares

Typically, the share of labor income is estimated either from the national accounts or from input-output tables. For example, using the data of Chinese input-output tables in 1992, 1995, 1997 and 2000, the ratios of compensation for laborers in the agricultural sector are 0.84, 0.84, 0.88, and 0.88, respectively. Not only are those numbers substantially higher than the estimates of non-agriculture sector by Young (2003), but also much higher than the shares in other East Asian countries[11]. This abnormal high share of labor input is due to the nature of agriculture that I have discussed in the previous sections. There is no observable labor income in the less developed countries, and according to OCED (2000), the compensation of labor from agricultural sector is calculated by summing all the "net incomes" of various activities associated with the production in the rural area. Therefore, the measure from the input-output tables contains not only the labor share, rather than a combination of different factor income.

To see this problem from a border perspective, I estimate the factor shares by an aggregate Cobb-Douglas production function. This approach is similar to Chow (1993), which shows the capital, labor and land shares are 0.25, 0.40 and 0.35 respectively for Chinese agriculture. The production function is specified as the followings:

$$\ln Y = \alpha_0 + \alpha_1 \ln K + \alpha_2 \ln A + \alpha_3 \ln L + \alpha_4 t$$

or with the constant return to scale assumption:

$$\ln \frac{Y}{L} = \alpha_0 + \alpha_1 \ln \frac{K}{L} + \alpha_2 \ln \frac{A}{L} + \alpha_4 t$$

where Y is the output, K is capital, A is area of land and L is labor. I exclude the years 1958-69, as Chow (1993) suggests, based on the assumption that those years

[11]Ohkawa (1979) reports the agricultural labor shares in Japan, Taiwan, Korea, and the Philippines range from 0.31 to 0.53 during the period of the beginning of twentieth century to the sixties.

are irregular due to the political movements during those periods, such as the Great Leap Forward and the Cultural Revolution. The coefficients of the variable inputs represent the factor shares in production. Variable t has a value of zero from 1952 to 1977 and increases by one thereafter. Thus, the coefficient of t can be read as the average productivity growth in Chinese agricultural sector after 1978.

The CSY provides us detailed data for output, labor and land before 1978. Since the price did not change hugely during the planned-economy period, we do not worry much about the real v.s. nominal problem as we do for the reform period. For capital, the CSY doesn't break down the capital into different sectors, so I rely on the investment data estimated by Chow (1993). I set the initial capital in 1952 such that my constructed capital series matches the data in 1978 from previous section.

Table 5 shows the regression results. The coefficients of capital from both regressions are almost identical, and they both indicate that the factor share of capital is about 25%, which is consistent with Chow's estimate. The two regressions also suggest there is an 4% increase in productivity for the Chinese agricultural sector in 1978-2005. This number is very similar to my estimate from using micro level data.

Overall, the TFP growth can be estimated by the following:

$$\text{TFP growth} = \frac{d\ln Y}{dt} - v_K\frac{d\ln K}{dt} - v_L\frac{d\ln L}{dt} - v_T\frac{d\ln T}{dt}, \tag{23}$$

where v_K is the capital share, v_L is the capital share, and v_T is the land share.[12] I have shown that for Chinese economy from 1978 to 2003, agricultural output grows at 5.6% annually, capital grows at 3.1%, labor input decrease at a rate of 2%, and land barely changes and only increase by 0.3% each year. The capital share is 25%, labor share is 37%, and land share is 38%. The TFP growth is calculated as equation (23), which yields a 5.4% annual growth.

[12] See Denison (1985) and Jorgenson et al (1988) for a similar approach for the U.S. economy.

5 A Simple Calibration

Now I calibrate the model to investigate the effect of agricultural productivity to the equilibrium dynamics for the Chinese economy. I choose a period to be a year and take the initial year as the first year for China to implement the economic reform, 1978. All technological parameters for agriculture and manufacturing sectors rely on the estimation result of this paper and Young (2003), respectively. The technological changes in both agricultural and manufacturing sectors take the labor augmenting form, which implies:

$$\mu_a = 5.4\% \times (1 - \alpha_a),$$

$$\mu_m = 1.4\% \times (1 - \alpha_m).$$

I use my estimate of labor share, 38%, in the agricultural sector from the previous section and Young (2003) shows the manufacturing labor share is 46%. These two figures indicate that the agricultural sector is relatively capital (including land) intensive compared with manufacturing. This is another factor to drive down agricultural price by equation (11). Furthermore, I choose a 1% annual population growth rate, $v = 1\%$, a 5% annual depreciation rate for capital, $\delta = 5\%$, and a 3% annual discount rate, $\rho = 3\%$. The parameter ϕ represents the expenditure share of agricultural goods in the steady state and is set to 0.15.

Following King and Rebelo (1993), I choose the initial value of manufacturing capital-labor ratio, k_{m0},so that the manufacturing output per worker increases 7 times in 100 years. I normalize the starting values of the technology, A_{m0} *and* A_{a0}, to one. I choose the value of γ such that it yields the initial value of employment share of agriculture, $n_{a0} = 0.7$, to match the level of Chinese economy in 1978.

With the parameters' value and the initial conditions given, I can calibrate the model using the method explained in section 2. I am interested in answering two questions: Whether the model can track the pattern of Chinese economy after 1978? What is the key that determines the growth process? Simulation results are presented in Figures 3 and 4. The model is able to reproduce the structural change of post-reform Chinese economy. The model predicts that the share of agricultural employment starts at about 70% and decreases to 43% in 2005, tracking the historical data closely, and it will fall to 20% in 2050.

Furthermore, the speed of such decrease depends on the level of TFP growth in agricultural sector. Suppose that the TFPG is reduced to 2%, instead of my estimate of 5.4% (the simulation is shown in Figure 4). The reallocation of labor takes place very slowly. It requires more than 50 years for the share of agricultural employment to reach today's level, 50%. In 150 years, the share is still higher than 20%. Finally, I also investigate the effect of a subsistent level of food consumption on the structural change. Figure 4 shows that once $\gamma = 0$, the reallocation of labor would complete overnight. There is no surprise. With the minimum consumption accounts for 90% of food consumption at the beginning, a country must put most of its recourse in food production. Despite the willingness to smooth consumption over time, a high fraction of the labor force remains in the agricultural sector. Labor is released to the other sector only after technology progress and capital accumulation.

6 Conclusion

After a growth accounting exercise, this paper shows that the TFP growth in agriculture for China during the reform periods is about 5.4% and is much higher than the estimate of the non-agricultural sector by Young (2003). To account for the quality change of Chinese farmers, I estimate the shadow wage from the data of a household survey, using the level of inputs as a control for endogeneity problem, suggested by Levinsohn and Petrin (2003). My finding validates that most of the efficiency gain of the Chinese economic reform is in the agricultural sector. To investigate the role of agricultural productivity, I develop a growth model combining the sector difference in productivity and a subsistent level of food consumption. My calibration results track the data of agricultural employment share closely and show that the high TFP growth in the Chinese agricultural sector is the key to maintain the structural change.

Appendix for the Data Section

A Data Construction

Initiated in 1989, the CHNS was designed as a time-cohort survey and covers nine provinces: Heilongjiang, Liaoning, Shandong, Jiangsu, Henan, Hubei, Hunan, Guangxi, and Guizhou. These provinces vary substantially in geography, economic development, public resources, and health indicators; therefore, this survey is able to provide nationally representative data for the purpose of this study. Multiple types of agricultural outputs from different production activities for a household, such as farming and fishing, are aggregated together as a single measure of the total output. Also added in are the farmer's self-consumption parts of each agricultural product. The costs associated with each production activity are included in the survey as well. Therefore, I calculated the total expenditure in production by summing all of the costs in each category. All the monetary variables are deflated by community-level commodity-specific price indexes[13] and are expressed in 1993 yuan. For each type of production, participating individuals were asked three questions related to their labor input in agriculture: on average how many hours of work per day, how many days of work per week, and how many months of work per year. Those three answers, along with the assumption that on average a month contains 4.3 weeks, provide us with the amount of an individual's working hours per survey year.

B Intermediate Input as A Proxy

Olley and Parkes (1996) addresses the endogeneity problem differently by using investment as a proxy for the unobserved productivity. More precisely, under certain assumptions, the productivity is a monotonic function of investment and capital, and the coefficients of the inputs is estimated by a semiparametric method. Levinsohn and Petrin (2003) modifies this approach by suggesting the intermediate input

[13] Community level data are not available for download online, but those price data can be obtained by application from the Carolina Population Center.

as a proxy instead of investment. This is mainly data-driven, because many firms report zero investment, but almost every firm uses positive amount of intermediate inputs. I take the intermediate-input approach in this paper for the same reason. Let's consider the following production function with only one type of labor input (in logs):

$$Y_t = \beta_0 + \beta_l L_t + \beta_a A_t + \beta_c C_t + \omega_t + \varepsilon_t \tag{24}$$

where Y_t is the total output, L_t is the labor input, A_t is the land input, and C_t is the intermediate input. The error terms are divided into two parts: the ω_t represents the productivity shocks that is not observable from researchers, but can be realized by the household when they are making input-time allocation decisions. The ε_t is an i.i.d. component that has no influence on household decisions. The intermediate input depends on the productivity shock ω_t and the state variable A_t, and is determined by a function f:

$$C_t = f_t(\omega_t, A_t). \tag{25}$$

Under the assumption that the intermediate input is monotonic in the productivity shock ω_t for all possible level of A_t, inverting (25) gives us:

$$\omega_t = f_t^{-1}(C_t, A_t)$$

This function allows us to identify the coefficient in the labor input. To see this, rewrite (24) as:

$$Y_t = \beta_l L_t + \phi_t(C_t, A_t) + \varepsilon_t, \tag{26}$$

where

$$\phi_t(C_t, A_t) = \beta_0 + \beta_a A_t + \beta_c C_t + f_t^{-1}(C_t, A_t).$$

As Petrin et al. (2004) suggests, ϕ_t is treated nonparametrically as a third order polynomial function and β_l can be estimated consistently from (26) by applying

OLS to the following equation:[14]

$$Y_t = \beta_l L_t + \sum_{i=0}^{3} \sum_{j=0}^{3-i} \delta_{ij} C_t^i A_t^j + \varepsilon_t.$$

[14] To identify β_c and β_a needs further assumptions on the process of ω_t, but in this paper I focus on estimating β_l consistently.

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Table 1. Description, Means and Standard Deviation of Key Variables.

	Description	Mean	Std. Dev.
Output	Total value of all household agricutural product included self- consumption.	3798	6011
Adult Male	Hours work for male, age > 19	1355	1328
Adult Female	Hours work for female, age >19	1479	1293
Land	Land area in *mu* (1 *mu* = .067 hectares)	13.3	24.2
Cost	Total expenditure from production.	1548	2053
Survey Year	1993, 1997, 2000 and 2004		

Notes: All the means are calculated condition on positive value.

Table 2 Estimates of A Simple Cobb-Douglas Production Function

Educational Level and Age	Under Primary		Primary		Secondary		Tertiary	
	Male	Female	Male	Female	Male	Female	Male	Female
15-19	-0.018	-0.030	-0.011	-0.014	-0.00018	-0.016	0.015	-0.10
	(0 .029)	(0.024)	(0.018)	(0.019)	(0.012)	(0.014)	(0.055)	(0.068)
20-24	-0.047	-0.020	-(0.033	-0.050	-0.024	-0.0084	-0.059	-0.033
	(0.027)	(0.020)	(0.016)	(0.016)	(0.010)	(0.012)	(0.024)	(0.036)
25-29	0.029	-0.032	-0.0059	-0.0021	0.010	-0.015	-0.042	0.041
	(0.022)	(0.016)	(0.015)	(0.013)	(0.010)	(0.011)	(0.023)	(0.039)
30-34	0.051	0.0029	0.029	0.024	0.019	0.0074	-0.012	-0.019
	(0.027)	(0.014)	(0.016)	(0.012)	(0.0095)	(0.0096)	(0.017)	(0.022)
35-39	0.0081	-0.011	0.038	0.037	0.047	0.033	0.015	0.011
	(0.019)	(0.011)	(0.015)	(0.012)	(0.0097)	(0.0098)	(0.014)	(0.017)
40-44	-0.0041	0.0078	0.015	0.029	0.032	0.020	0.049	0.073
	(0.016)	(0.0090)	(0.012)	(0.011)	(0.0098)	(0.011)	(0.014)	(0.017)
45-49	0.030	0.025	0.027	0.044	0.048	0.054	0.059	0.022
	(0.013)	(0.0082)	(0.011)	(0.011)	(0.0099)	(0.013)	(0.017)	(0.025)
50-54	0.020	0.030	0.030	0.046	0.076	0.066	0.052	-0.0079
	(0.012)	(0.0083)	(0.010)	(0.011)	(0.012)	(0.016)	(0.025)	(0.052)
55-59	-0.016	0.017	0.046	0.074	0.042	0.038	0.038	0.12
	(0.012)	(0.0091)	(0.012)	(0.015)	(0.014)	(0.027)	(0.034)	(0.055)
60-64	0.029	0.014	0.040	0.053	0.057	0.053	0.016	n.a.
	(0.012)	(0.0098)	(0.016)	(0.0230	(0.020)	(0.046)	(0.047)	
Aged 65	0.011	-0.0013	0.051	0.016	0.028	-0.062	0.023	n.a.
and Over	(0.010)	(0.0088)	(0.018)	(0.033)	(0.025)	(0.062)	(0.057)	

Table 3 Distribution of the Agricultural Working Population by Sex, Education, And Age

	1993	1997	2000	2004
	Sex			
Male	0.48	0.49	0.49	0.47
Female	0.52	0.51	0.51	0.53
	Education			
Under Primary	0.25	0.22	0.18	0.15
Primary	0.36	0.37	0.36	0.35
Secondary	0.32	0.34	0.38	0.40
Tertiary	0.07	0.07	0.07	0.10
	Age			
< 20	0.08	0.06	0.04	0.05
20-24	0.11	0.08	0.05	0.03
25-29	0.10	0.11	0.08	0.05
30-34	0.11	0.12	0.10	0.08
35-39	0.13	0.10	0.13	0.11
40-44	0.13	0.13	0.11	0.12
45-49	0.10	0.13	0.14	0.13
50-54	0.08	0.10	0.13	0.14
55-59	0.05	0.07	0.08	0.11
60-64	0.04	0.05	0.06	0.08
≥65	0.06	0.06	0.07	0.10

Table 4 Average Annual Growth Rate of Agricultural Labor Input and Quality by Country (%)

China:				
	1993-1997	1997-2000	2000-2004	1993-2004
Labor Input	-1.34	-4.36	-0.86	-1.99
Quality	0.92	1.88	0.96	1.20
U.S.:[a]				
	1960-1965	1965-1970	1970-1979	1960-1979
Labor Input	-6.67	-3.12	-1.89	-3.47
Quality	-0.10	0.31	1.80	0.90
Japan:[b]				
	1949-1959	1960-1970	1971-1979	1949-1979
Labor Input	-3.71	-3.34	-2.15	-3.12
Quality	0.61	0.81	0.05	0.51

a. Source: Jorgenson et al. (1987), Table B.1 and author's calculation.

b. Source: Imamura (1990), Table 12.1 and 12.2.

Table 5. Agricultural Production Function

Period[a]	ln K	ln L	ln Land	ln K/L	ln Land/L	Trend	R^2
1952-1980[b]	0.25 (0.044)	0.32 (0.095)	1.034 (0.24)				0.98
1952-2003[c]	0.26 (0.082)	0.39 (0.15)	0.68 (0.46)			0.039 (0.003)	0.99
				0.25 (0.081)	0.37 (0.081)	0.04 (0.003)	0.97

Note: Standard errors in parentheses.

a. The periods of 1958 to 1969 are excluded from the estimations.

b. Source: Chow (1993).

c. Source: author's extension based on the investment data of Chow (1993).

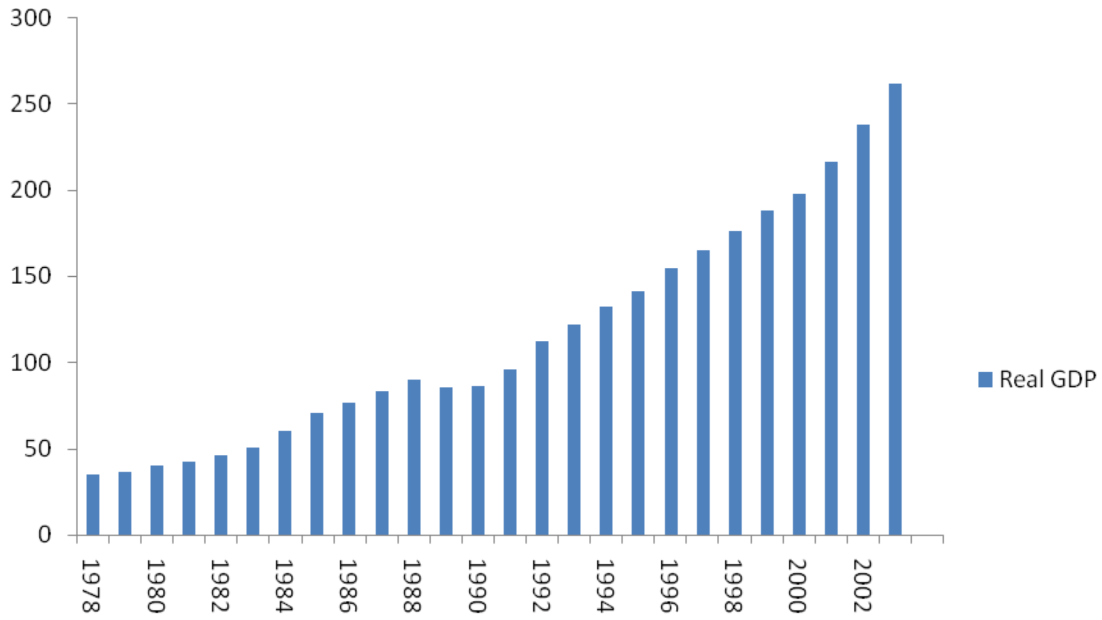

Figure 1: Real GDP in China (10 Billion of 1978 RMB)

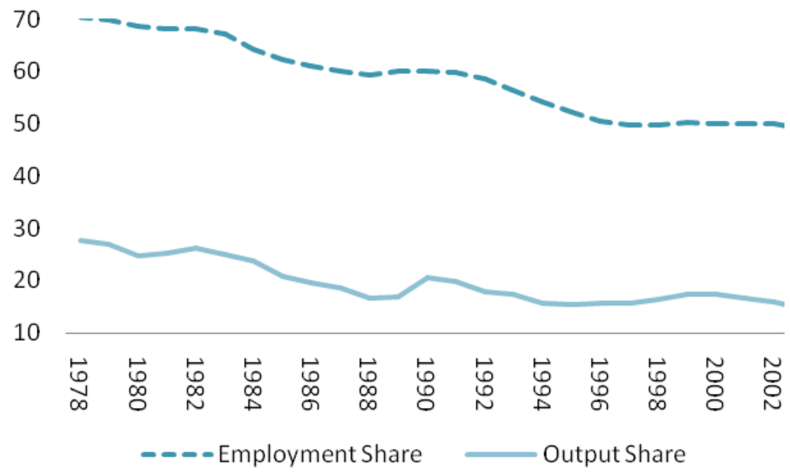

Figure 2: Declining Role of Agriculture (%)

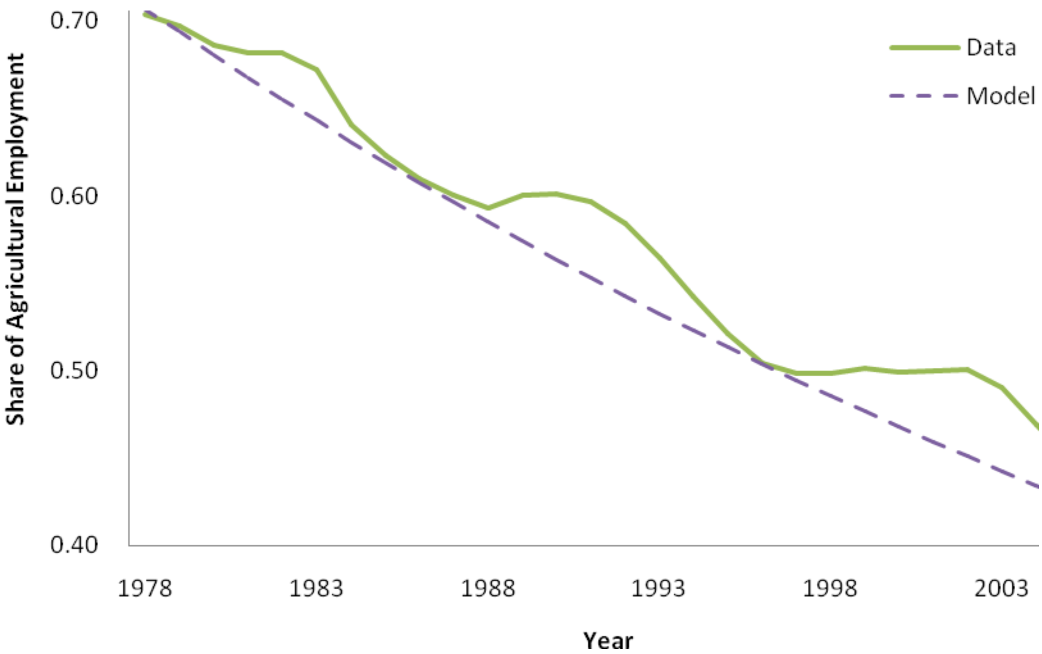

Figure 3: Shares of Agricultural Employment, Data and Model, 1978-2005.

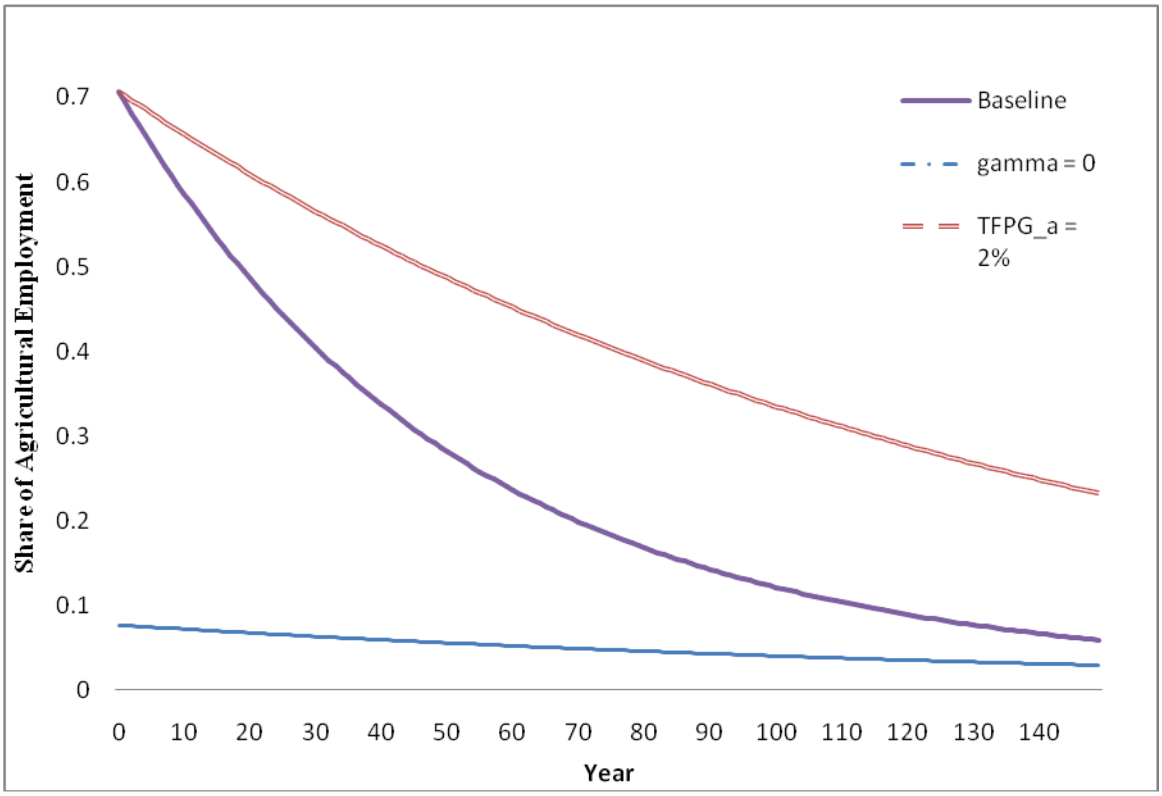

Figure 4: Shares of Agricultural Employment, Baseline and other experiments.