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Reforms, Incentives, Welfare and Productivity Growth in Chinese Wheat Production

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Abstract:

Following the rural reform in 1978 a series of agricultural reforms were introduced in China with an aim to create incentives for the farmers to produce more. The nineties' price reform that was aimed at deregulating the agricultural market eventually resulted in a huge drop in agricultural production; this apparently motivated the government to take over the control of agricultural prices in 1998. For a dataset that covers all the major rural reforms undertaken in China, we examine how and to what extent these reforms affected the productivity and welfare of wheat farmers in China. We find that the nineties' price reforms resulted in a high magnitude of effort-response from wheat farmers which led to a faster growth of the incentive component of productivity. Due to random weather shocks this response did not result in the expected level of profit and as a result the farmers suffered a decline in welfare. The regulations introduced in 1998 destroyed the incentive-induced growth in TFP. In general wheat farmers in China responded highly when markets were made more competitive, and their effort-response for flat subsidies (e.g. the ones introduced in the eighties) was very marginal.

JEL Codes: N55, O13, O53, Q12.

Keywords: China, Incentives, TFP, Agriculture, Wheat Production.

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1 Introduction

Since 1978 a series of agricultural policy reforms were gradually introduced in China in order to shift the agricultural commune system towards a more liberalized agricultural market system. These reforms were mainly aimed at achieving a higher level of aggregate production of major foodgrains and a higher level of productivity of farmers. According to the United States Department of Agriculture (USDA) 2008 data, China is one of the largest producers of wheat in the world accounting for approximately 17% of the world's wheat production[2]. In this paper we examine if, how and to what extent the incentives introduced through the policy reforms during the period 1978-2007 contributed to the growth in wheat production, to the growth in farmers' productivity, and to farmers' welfare in China.

This paper is important for three reasons. First, in this paper we examine how farmers in China react to reforms, where reforms are directed towards providing farmers the incentive to produce and sell wheat more competitively. Based on an analytical framework where we assume that the farmers are profit-maximizers and they choose the effort level that is optimal, we empirically examine the farmers' effort-response for the full set of agricultural reforms undertaken in China. We explore this framework in order to study how profit maximizing farmers respond to changes in policy and institutions. Second, we examine how reforms affect the growth in the Total Factor Productivity (TFP) of wheat production[3] and the growth in the incentive component of this TFP for a country that has experienced a series of interesting reforms and weather shocks and currently is one of the largest producers of wheat. In doing so we use the most recent available dataset which covers almost a decade following the last important reforms. In this way our study extends important previous studies, such as Zhang and Carter (1997), Lin (1992), and McMillan et al. (1989)[4].

We also extend these works (and others, such as Che et al., 2001, Kompas, 2005 and Selim and Parvin, 2010) by simulating the effect of policy reforms on the welfare of farmers. Through the welfare analysis, we examine if and to what extent policy reforms have contributed to the improvement of living for the wheat farmers in China, which is the third important contribution of this paper.

[2] India, USA and the European Union are the other largest producers of wheat, see USDA Wheat database for details.

[3] If wheat production function is $Q = Af(X_1, X_2, ..., X_n)$, where Q denotes total output of wheat, $X_is, i = 1, 2, ..., n$ denote the quantities of n inputs used in producing Q, Total Factor Productivity (TFP) of wheat production, denoted by A, is the portion of wheat output not explained by the amounts of inputs used in production. As such, its level is determined by how efficiently and intensely the inputs are utilized in wheat production.

[4] None of these studies consider the most recent important agricultural reform in China that was introduced in 1998. In this paper we consider a dataset which is for 1978-2007, i.e. a dataset that covers all the major agricultural reforms in China.

We follow the approach as in Hayami and Ruttan (1985), which McMillan et al. (1989), Lin (1992) and Zhang and Carter (1997) explore to study foodgrain productivity growth in China for 1978-84, 1970-87 and 1979-86, respectively[5]. Typically in economies in transition factor price and product price increase at different rates with market reforms. We characterize this process through a weighted cost-share parameter of wheat production in China, which is the ratio of average factor to product prices. As is true for most economies in transition, the value of such a cost-share parameter falls over time with market reforms which in turns results in higher profits. We assume that farmers are profit maximizers, therefore they will choose effort levels that are optimal. We use the farmers' optimal effort function in order to transform a technical wheat production function into a production function that captures the farmers' optimal response to changes in institutions and policy. We estimate the transformed function using panel data of 30 wheat producing regions of China for the period 1997-2006.

We use the estimated factor share parameters, other parameters of the model, and time series of *aggregate* level data of factor and wheat prices for China for the period 1978-2007 in order to simulate the time path of TFP and the time path of its incentive component. This enables us to capture the TFP growth and the growth in the incentive component of this TFP for all policy regimes. In addition, we use the computed parameters to generate a utility index and a time path of optimal effort levels for the entire reform period. Typically, the incentives that are introduced through the reforms result in higher level of effort, which in turns adds to the *disutility* of wheat farmers. But since farmers like profits, the increase in profit (resulting from the higher level of effort) adds to the *utility* of wheat farmers. The utility level resulting from a particular reform (or a series of reforms) would therefore depend on which effect dominates. We compute the utility index for the entire reform period which enables us to examine how policy reforms affected the welfare of wheat farmers in China.

We find that compared to the incentives introduced through the rural reforms in the early eighties, the incentives introduced through the price reforms of the nineties accounted for a greater response from wheat farmers. This response led to higher effort levels in the nineties. However, presumably due to the series of droughts in the early nineties the extended efforts did not result in higher profits in wheat production, which is possibly why we find that during this phase the farmers suffered a large drop in welfare. We find a further drop in welfare of farmers following the most recent reform of 1998 when the government took over the control of agricultural prices. Our results also suggest that wheat production

[5] Che et al. (2001) and Che et al. (2006) use a similar approach to examine the productivity in rice cultivation in Vietnam, and Selim and Parvin (2010) follow a similar approach to examine the extent of rice farmers' response to incentives in Bangladesh.

in China experienced an increase in TFP immediately following the early stages of reforms, and the main channel of this growth was the incentive component of TFP. By taking over the control of prices in 1998, the government destroyed the growth in the incentive component of TFP. In general we find that wheat farmers in China responded positively to reforms that led to more competitive market structure, and their effort-response to the introduction of flat subsidies or regulated pricing was very little.

2 A Brief History of Chinese Agricultural Reforms

We consult four main sources, namely, the various publications of the Ministry of Agriculture of the People's Republic of China (MOA, hereafter), Harrold (1992), Carter (2003) and Tong et al. (2003) in summarizing the major agricultural policy reforms that were undertaken in China. In 1976 when the communist leader Mao passed away, the new leadership led China into a period of great economic reforms starting with the rural reforms. The rural reforms began by changing the agricultural production system from the commune system to one of the household contract responsibility system in 1978. Under this new system the farmers were given a long term lease on the land that they farmed and instead of transferring all their produce to the government they were allowed to keep some and sell it at market prices to make a profit.

The government apparently recognised the need for specialization and the notion of absolute advantage and realized that it would be more efficient to allocate certain crops to specific provinces. Harrold (1992) finds that this reform led to a 25% (average) real increase in relative agricultural prices, which in turns acted as an incentive to produce more[6]. The state monopoly of allocating agricultural land was abolished so that the farmers could set up diversified businesses such as township enterprises. These reforms allowed a greater freedom for the farmers which resulted in their attempt to take advantage of the incentives to produce more with a greater level of efficiency.

As a support towards the first step of liberalization, in 1984 the government introduced an increase in price subsidy. In the following year the government left its role as the state monopoly of agricultural trade and established a market based contract structure. In 1986 the government introduced a scheme of increased subsidies to cereal production. During this regime there was also an increase in the chemical fertiliser supply, resulting in an increase in aggregate production levels of crops (see Tong et al., 2003 for details).

[6] Halbrendt and Gempesaw (1990) and Sicular (1988) also find that the initial stage of rural reforms in China led to an increase in the price levels of agricultural inputs.

The reforms in the nineties were mainly price reforms which together with the aforementioned changes enabled farmers to make many decisions on their own. As the years progressed so did the level of technology, and farmers in China started to adopt the new technology package which enabled further diversification. Research and development into seeds and fertilizer contributed to the increase in production. Apart from the rural reforms, several other policy reforms such as the state owned enterprise reform, social sector reform and the financial sector reform undertaken in the late eighties and the early nineties were aimed at providing a sound policy environment towards agricultural growth. The sequence of reforms posed a need for a reform on the prices. The government undertook the two-tier price reform in 1988 and in 1991. The first of these reforms affected the non-staple products, while the second affected the grain and the oil seed prices (see Harrold, 1992 for details). These reforms were aimed at promoting the market based trade of agricultural inputs and output. Prior to these reforms, the government played a major role in determining all the prices of goods and services.

However, in 1998 the government introduced the grain self-sufficiency system. Through this reform the government again took over the control of the grain prices. This move by the government altered the incentive structure that were previously introduced. This reform allegedly is a result of a decade of low growth in agricultural production in China, when the growth rate in rice production and wheat production dropped from 4.89% and 7.32% to 1.39% and 2.08%, respectively (see Pingali and Heisey, 2001 for details).

According to the reports of the MOA, the rural reforms led to development in agricultural productivity, rejuvination to the rural economy, improvement in living standards, and a sustained and rapid level of economic development. With the introduction of the grain self-sufficiency system in 1998 when the government took over the control of grain prices, the government committed to continue reforms that are aimed at improving the level of agricultural productivity, devising a farmland protection system, promoting agricultural structure readjustment, strengthening the agricultural service system, improving the rural distribution system, intensifying the rural reforms and expanding and opening up China to the rest of the world.

Apart from the policy reforms which created impacts on agricultural production and productivity, certain environmental shocks and global political as well as economic events are often alleged to have affected agricultural production in China. The Asian financial crisis caused a deceleration of the Chinese economy. This crisis happened just before the grain self-sufficiency system was introduced. China joined the World Trade Organization (WTO) in 2001 which enabled a greater amount of trade on the foreign market, resulting in a greater amount of competition in the local market (BBC 2010b). In 2003, the outbreak of the Sars Virus forced the Chinese farmers into quarantine restrictions (BBC 2010a). The global financial crisis of 2009 affected the major markets of the world including China's major export markets. There were also a number of natural disasters such as the droughts faced in 1991, 1992, 1994, 1997 and 2006, and the snowstorm and earthquake in 2008, which are held partly responsible for not only the contemporaneous loss in agricultural output but also for adverse long term effects on the conditions of agricultural land and infrastructure.

In this paper we mainly focus on the hypothesis that the main reason of the changes in agricultural productivity in China is the changes in the incentive structures that were introduced through the policy reforms. We consider three stages of agricultural policy reforms, namely, (1) the rural reforms 1979-1984, when agricultural markets were partly liberalized (the partly liberalized regime), (2) the rural reforms 1985-1997, when agricultural markets were fully liberalized (the liberalized regime), and (3) the rural reforms 1998-2007, when the state took over the control of agricultural prices (the grain self-sufficiency regime). Our empirical methodology enables us to characterize the changes in the incentive structures that were introduced through these three regimes and their resulting impact on the TFP of wheat production. In order to account for the incentive-induced changes in productivity we decompose TFP of wheat production into an *incentive* component and an *other* component. While our key focus will be on the incentive component of TFP, the other component of TFP is assumed to account for exogenous random shock-induced changes in TFP of wheat production.

3 The Analytical Model

We assume that the production of wheat requires four inputs: effective contribution of labour, effective use of machinery power, land, and the total amount of fertilizers. Let ε_N denote the level of effort of a typical farmer so that in a model with N farmers, $\varepsilon_N N$ is the effective contribution of farmers' working time measured in efficiency units[7]. Since managing the use of machinery power is a major source of concern for a typical farmer, we capture the management of machinery power through another effort variable, denoted by ε_M, i.e. if M denotes the total power of the machinery used in wheat production, ε_M captures the effort associated with exploiting and managing the machinery power[8]. Measured in efficiency

[7] The value of ε_N in this model is one that includes everything that determines the quality of the farmers' working time as well as the willingness of exert more effort due to the enhanced incentives that accompany agricultural reforms.

[8] In this model ε_M is a proxy for machinery management skills of a typical farmer, but the execution of this skill requires hard work, something which the farmers do not like.

units, the total input of machinery power in wheat production is therefore $\varepsilon_M M$.

With $a_0 \in (0,\infty)$ and $a_i \in [0,1]\,, i=1,2,3,4$, such that $\sum_{i=1}^{4} a_i = 1$, the *technical* constant returns to scale (CRTS) production function for wheat is:

$$Q = a_0 \left(\varepsilon_N N\right)^{a_1} \left(\varepsilon_M M\right)^{a_2} \left(L\right)^{a_3} \left(F\right)^{a_4} \tag{1}$$

where Q denotes the total output of wheat, L denotes the sown area of wheat, and F denotes the total amount of fertilizer used in wheat production. In per capita terms, the production function is

$$q = a_0 \left(\varepsilon_N\right)^{a_1} \left(\varepsilon_M m\right)^{a_2} l^{a_3} f^{a_4} \tag{2}$$

Let p denote the market price of wheat, and $\omega_i, i=1,2,3,4$, denote the price of input i. Farmers choose the least cost combination of inputs. The total cost function, with $\xi > 0$ (a constant) is given by:

$$TC = \xi \prod_i \omega_i^{a_i} Q \tag{3}$$

With the average real input price $\Lambda\left(\omega\right) = \prod_i \omega_i^{a_i}$, the cost of production per farmer is:

$$C = \xi \Lambda\left(w\right) q \tag{4}$$

Let $\phi \equiv \frac{\Lambda(\omega)}{p}$, which is the ratio of the observed average input to output prices. The farmer's profit function is:

$$\pi = pq\left(1 - \xi\phi\right) \tag{5}$$

Farmers utility is defined over profits and the effort levels. They like the profits but dislike the effort of hard work and the effort of planning more efficient use of the machinery power. Their utility function is:

$$U\left(\pi, \varepsilon_N, \varepsilon_M\right) = \pi - \sigma\theta\left\{\left(\varepsilon_N\right)^{\frac{1}{\sigma}} + \left(\varepsilon_M\right)^{\frac{1}{\sigma}}\right\} \tag{6}$$

with $\sigma \in (0,1)$ and $\theta \in (0,\infty)$[9]. With (2) and (5), we can write the farmers' utility maximization problem as:

$$\max_{\varepsilon_N, \varepsilon_M} U\left(\varepsilon_N, \varepsilon_M\right) = \left[p a_0 \left(\varepsilon_N\right)^{a_1} \left(\varepsilon_M m\right)^{a_2} l^{a_3} f^{a_4}\left(1-\xi\phi\right) - \sigma\theta\left\{\left(\varepsilon_N\right)^{\frac{1}{\sigma}} + \left(\varepsilon_M\right)^{\frac{1}{\sigma}}\right\}\right] \tag{7}$$

[9] With (6), the marginal *utility* of profit is constant and the marginal *disutility* of effort is increasing in the level of effort. Without loss of generality we assume that the parameter σ in (6) is identical across both types of effort.

The optimal values of effort levels satisfy

$$(\varepsilon_N^*)^{\frac{1}{\psi\sigma}} = \frac{1}{\theta} p\,(1-\xi\phi)\, a_0 m^{a_2} l^{a_3} f^{a_4} a_1^{(1-\sigma a_2)} a_2^{\sigma a_2} \tag{8}$$

$$(\varepsilon_M^*)^{\frac{1}{\psi\sigma}} = \frac{1}{\theta} p\,(1-\xi\omega)\, a_0 m^{a_2} l^{a_3} f^{a_4} a_2^{(1-\sigma a_1)} a_1^{\sigma a_1} \tag{9}$$

where $\psi \equiv \frac{1}{1-\sigma(a_1+a_2)}$.

Proposition 1 *The optimal effort level in work is a fixed proportion of the optimal effort level in planning the use of machinery power.*

Proof. Consider (8) and (9) which together imply

$$\frac{\varepsilon_N^*}{\varepsilon_M^*} = \left[\frac{a_1^{(1-\sigma a_2)} a_2^{\sigma a_2}}{a_1^{\sigma a_1} a_2^{(1-\sigma a_1)}}\right]^{\sigma\psi} \tag{10}$$

and therefore

$$\varepsilon_N^* = \left(\frac{a_1}{a_2}\right)^{\sigma} \varepsilon_M^* \tag{11}$$

and the fixed proportion depends on a_1, a_2 and σ. ■

The optimal levels of effort given by (8) and (9) depend on, among others, the output and input prices. In transition economies, prices of inputs and the price of output generally increase at different rates with reforms. This process is characterized by the share-cost parameter ϕ. Any change in this parameter will affect the farmers' optimal effort-response. Thus any change in policy and institutions that alters the price of agricultural inputs and/or the market price for wheat is captured by the change in the level of effort by a typical farmer. Together with the changes in output and inputs prices which alter the profits of a typical farmer, changes in the optimal effort level thus guide the change in TFP and the change in utility.

We substitute (8) in (1) in order to derive the *institutional* production function, i.e. the production function that captures farmers' optimal response to changes in market and institutions:

$$Q = A\,(N)^{\gamma_1}\,(M)^{\gamma_2}\,(L)^{\gamma_3}\,(F)^{\gamma_4} \tag{12}$$

where the total factor productivity (TFP) coefficient A is given by:

$$A = (a_0)^{\psi}\left[\frac{1}{\theta} p\,(1-\xi\phi)\right]^{(a_1+a_2)\sigma\psi} (a_1)^{a_1\sigma\psi}\,(a_2)^{a_2\sigma\psi} \tag{13}$$

and the share parameters in (12) are

$$\gamma_1 = \psi \left[a_1 - \sigma \left(a_1 + a_1\right)\right] \tag{14a}$$
$$\gamma_2 = a_2 \psi \tag{14b}$$
$$\gamma_3 = a_3 \psi \tag{14c}$$
$$\gamma_4 = a_4 \psi \tag{14d}$$

for working time, machinery power, land and fertilizers, respectively. The institutional production function (12) introduces the empirical relevance to the model. With $\sigma \in (0,1)$, and $a_i \in [0,1], i = 1,2,3,4$, such that $\sum_{i=1}^{4} a_i = 1$, $\psi > 0$ and therefore $\gamma_i s$ are empirically different from $a_i s$. In this way, we have transformed a technical production function into an *institutional* production function for which the TFP coefficient captures the farmers' optimal response to changes in policy and institutions. With obervable data we estimate the institutional production function, (12).

The TFP coefficient in (13) can now be decomposed into two components, which are:

$$A_{inc} = \left[p \left(1 - \xi\phi\right)\right]^{(a_1+a_2)\sigma\psi} \tag{15}$$

and

$$A_{other} = (a_0)^{\psi} \left[(a_1)^{a_1} (a_2)^{a_2} \left(\frac{1}{\theta}\right)^{(a_1+a_2)}\right]^{\sigma\psi} \tag{16}$$

In this way, the institutional production function assists in explaining the incentive induced growth in TFP. More specifically, A_{inc} is the incentive component of TFP in wheat production, i.e. the component that changes due to changes in output and input prices, and A_{other} is the unexplained component of TFP, and clearly,

$$\left(A_{inc}\right)\left(A_{other}\right) = A \tag{17}$$

As in (15) and (16), the component A_{other} is fixed while the component A_{inc} varies with the level of profits. When reforms generate incentives to produce more, farmers earn higher profits and the term $p\left(1 - \xi\phi\right)$ in (15) increases resulting in higher levels of incentive-induced growth in TFP.

4 Data and Estimation

In this paper we estimate (12) using panel data for thirty regions of China over the period 1997-2006. We then use the estimated parameters and the constant returns to scale assumption in (14) in order to pin down the values of the 5 unknowns in (14), i.e. $a_i \in [0,1], i = 1,2,3,4$, and σ. Once these are pinned down, we simulate the time path of A and A_{inc} using time series of national wheat production aggregates (inputs and output) over the three regimes, i.e. for the period 1978-2007. This enables us to compare the trend in TFP with the trend in the incentive component of TFP, and also the growth in TFP and the growth in the incentive component of TFP of wheat production in China.

4.1 Data

Our main data source is the Economic Research Service (ERS) at the United States Department of Agriculture (USDA) that use the Statistical Yearbook published by the National Bureau of Statistics, China (SYB, CBNS)[10]. Summary statistics for the panel data (regional level) including the description of variables are presented in table 1 (in appendix A). The time series data on wheat output and inputs used for wheat production are in figure 1a, and the time series of input and output price indices and the computed profit index are in figure 1b (in appendix B). The summary statistics for the time series data on inputs and output are in table 2 (in appendix A).

The data that are available from these sources, both for the regional and the national aggregate level, include output of wheat as the total wheat production measured on an annual basis in 1000 tons. The total area of cultivated land and sown area for wheat are both in 1000 hectares. Agricultural employment is in millions[11]. The machinery data is the total power of agricultural machinery (in 10000 kw) used in farming, forestry, animal husbandry, and fishery, including ploughing, irrigation and drainage, harvesting, transport, plant protection and stock breeding. Fertilizer data is the quantity of chemical fertilizer (in 10000 tons for regional data) applied in agriculture during the year, including nitrogenous fertilizer, phosphate fertilizer, potash fertilizer, and compound fertilizer. We convert the data in per hectare form, i.e. we first compute the proportion of total cultivated land that is cultivated for wheat production. We use this proportion to derive output of wheat

[10] The input and output data for wheat production is collected from the Department of Rural, Social and Economic Survey. The input and output price data are collected from the Department of Urban, Social and Economic Survey.

[11] This agricultural labour force refers to the total labourers who are directly engaged in farming and receive remuneration payment or earn business income in the farming sector. For regional level data the agricultural employment is in 10000 persons.

per hectare, power of machinery used per hectare and chemical fertilizer used per hectare. The labour data is taken in the form of person days per hectare. This is calculated by multiplying the labour force by the ratio of the total sown area of wheat and the total area of cultivated land, and then dividing the result by three hundred (the approximate number of working days in one year).

The input price and output price data that we use are the national level averages. The price of wheat is taken from the USDA. This price data is the producers' price index for wheat computed using a geometric mean approach. Because farmers in China are required to pay an agricultural tax for land use, we use the (per hectare) revenue collected from this tax as a proxy for land rental. The wage data is the average wage of agricultural workers, in money terms per person over one year. The price for farm machinery and the price for chemical fertilizer are collected from Statistical Yearbook of CBNS. We collect net income per capita which is the total income of the permanent residents of the rural households during a year after the deduction of the expenses for productive and non-productive business operation, the payment for taxes and the payment for collective units for their contracted tasks. This net income data is our proxy for net profits of farmers. This data is required in order to pin down the parameter ξ using (5). For the simulations we convert all price data and the net profit data into indices with 1978 as the base year.

4.2 Estimation, diagnostic tests and computations

We estimate (12) using many combinations of cross section and period effects. These combinations are to account for the unobserved effect within a panel and the idiosyncratic errors in the model. Typically, assuming fixed effects within a panel estimation is equivalent to imposing time independent effects for each entity that are possibly correlated with the regressors. On the other hand, the random effects assumption is that the individual specific effects are uncorrelated with the regressors. We conduct a series of diagnostic tests for misspecification, the redundancy of the fixed effects, and the consistency of the random effects (where applicable). We present a summary of the estimated models and the main tests in table 3 (in appendix)[12].

In table 3, model 1 is estimated using simple OLS with no cross section and period effects. Models 2, 3 and 9 are estimated with the assumption of cross section fixed effects, and models 4, 5 and 8 are estimated with the assumption of cross section random effects. Models 5, 7 and 9 are estimated assuming that period effects are random, while models 3, 6

[12] In table 4 and table 6 we present summary of some important individual diagnostic tests.

and 8 are estimated assuming that they are fixed. The RESET tests for each model suggest misspecification in models 2, 4, 5, 8 and 10. The cross section fixed effects are found to be individually significant for models 2 and 9, while period fixed effects are found individually significant in models 6 and 8. For model 3 the cross section and period fixed effects are found to be jointly as well as individually significant. We find inconsistent random cross section effects in model 4 and 8, but for model 9 we find that the random period effects are consistent.

The wald test for the constant returns to scale in the production technology suggest that for 7 out of 10 specifications the CRTS assumption holds. We reject the CRTS assumption for specifications 1, 6, and 7. Summary of this test is in table 4. The coefficient estimates are generally statistically significant. We find significant negative marginal product of labour in specifications 1, 3, 5, 6, 7, 8 and 10. As it appears from the estimations, the coefficient estimates for land and machinery are the largest and these estimates are statistcially significant for all specifications except 2 and 4. Based on these estimates, we use (14) and the CRTS assumption in order to pin down the values for the parameters (except a_0) in the structural production function (1) and the utility function parameter σ, and these computed values (and other pinned down parameters) are reported in table 5. The reported value of a_0 in table 5 is derived in a later stage of the computations.

Based on the diagnostic tests, we choose two representative models, model 3 (one with fixed cross section and fixed period effects) and model 9 (one with fixed cross section and random period effects). The test summary for model selection which is primarily based on the significance of the fixed and random effects is in table 6. For both model 3 and model 9 the RESET test suggest no misspecification, and for both models the adjusted R^2 is very high relative to the others (the Akaike Information Criterion for model 3 is the lowest). For model 3 the cross section and period fixed effects are significant, while for model 9 the cross section fixed effects are significant and the random period effects are consistent[13].

We use the estimated γs of model 3 and model 9, the constant returns to scale assumption, and (14) in order to pin down two sets of estimates for $a_i \in [0,1], i = 1,2,3,4$, and σ. We then use these pinned down values, the index for inputs and output prices, and (15) in order to simulate the time path of A_{inc} for the two models. The time path for A is computed using standard growth accounting approach, where A is the standard Solow residual equivalent. Using (17) we then simulate a path for A_{other}. We fix $\theta = 1$ and use (16) in order to compute a series of a_0. In principle, the parameter a_0 should not vary over

[13] We conduct a standard Breusch-Pagan test for heteroscedasticity and find no heteroscedasticity for models 2, 3, 4, 5, 8, 9 and 10. The wald test for the overall significance of the estimation suggest that the estimated parameters for all these models are jointly significant.

time but the method we use to identify its value in this computation results in a series for this parameter. The computed value for this parameter is essential for computing a series for the optimal effort levels, which in turns will be used to compute a series of welfare levels. As is clear from (8), (9) and (6), any variation in the optimal effort levels and the level of (optimum) welfare over time is due to variations in input use and variations in input and output prices (and not a_0). We therefore compute the simple arithmetic average of the parameter a_0 from the series we generate, which we hold as its pinned down value[14]. These values are 1 for model 3 and 0.99 for model 9, both of which are reported in table 5.

These computations enable us to explore (8) and (9) in order to simulate the series of optimal effort levels ε_N^* and ε_M^*. Finally, using the simulated optimal effort levels, the pinned down parameter values, and the index for input and output prices we simulate a time path of the utility index (for both models). This enables us to examine the changes in welfare due to policy reforms. Given the anaytical model, any policy reform that alters the prices of inputs and output has two channels of affecting the welfare level: the enhanced incentives to earn higher profits (which adds to welfare), and the incentive to exert more effort to earn higher profits (which reduces welfare). Improvement in welfare due to a particular policy reform thus will depend on which of these two effects dominate. Intuitively, if the particular reform brings in a relatively higher rate of increase in the price of output it will affect both the profits and the optimal effort levels. Unless the net effect is numerically characterized, it is not possible to say if that reform will add anything to farmers' welfare.

5 Results and analysis

In figures 2a and 3a, we present the simulated path of A and the simulated path of A_{inc} and the path of their growth rates, respectively, that are computed using the estimated parameters for model 3. In figures 2b and 3b, we do the same for A and A_{inc} and their growth rates using the estimated parameters for model 9.

As in figure 3a, it appears that the policy reforms of 1978, 1991 and 1998 have had immediate effects on the growth of the incentive component of TFP of wheat production in China. This immediate effect does not mimic the contemporaneous variation in the growth in TFP, but there is evidence of a lagged correlation between the growth in these two series. The incentive component of TFP generally flattened out following the reform of 1984 and its

[14] We check for the sensitivity of our main findings (related to the changes in welfare) for a set of plausible values for θ, and find that this parameter only has level effects. We therefore present the key results for $\theta = 1$.

growth rate remained very low until the price reform of the early nineties. For both models we find a high growth in the incentive component following the introduction of the rural reform (the introduction of the partly liberalized regime in 1978), after which its growth rate continues to drop until the nineties. The eighties reforms (which were mainly based on price subsidies) did little in improving the growth in the incentive component of TFP, and during most of this regime TFP growth was negative. Following the introduction of grain self-sufficiency regime (i.e. when the government took over the control over prices) growth in the incentive component of TFP and growth in TFP both drastically fall.

These results suggest that wheat farmers in China in general respond to incentives that are introduced through the policy reforms. Their response which we capture primarily in the incentive component of TFP is an account of how they react to changes in policy and institutions. Flat subsidies in the eighties did not generate enough incentives for farmers which is why the incentive component of TFP suffered decline throughout most of the eighties. Growth in the incentive component also suffers following the most recent major reform in 1998. Overall the growth in this component is very minimal in the most recent regime, indicating that with the introduction of the grain self-sufficiency regime the government has destroyed the incentive-induced growth in TFP. This is also clear in the declining trend of the TFP series, as in figures 2a and 2b.

Until 1997 the main channel of growth in TFP of wheat production in China was the incentives that were introduced during the first two regimes. This finding is similar to the findings in Lin (1992) and Harrold (1992) which examine the productivity growth during the first phase of rural reforms. Our simulations suggest that the growth in the incentive component of TFP was reasonably high during 1993-1997. What apparently killed the growth in the incentive component of the TFP is the government's decision to take over the control on input and output prices, and even an increase in openness (when China joined WTO in 2001) which imposed a higher demand for Chinese wheat failed to generate enough incentives for wheat farmers.

We also find very little growth in the incentive component of TFP during 1986-1991, a period which is a part of the liberalized regime. This shows that the flat subsidies which were introduced in 1986 were rather ineffective in generating incentives to produce more. The positive growth in the incentive component of TFP in the early nineties were mainly due to the price reforms, which in turns imply that in China price reforms and liberalization of agricultural markets in general are more effective than flat subsidies or state regulations in generating incentives for farmers to produce more.

5.1 Reforms and changes in welfare

The simulated welfare index and its growth for 1978-2007 are presented in figures 4 and 6. The simulated optimal effort levels for the same time period are in figures 5 and 7. The welfare indices are simple computations of the utility as defined by (6) using the computed profit index, pinned down parameter values (including $\theta = 1$) and the optimal effort levels for 1978-2007.

As it appears, wheat farmers' optimal effort levels experienced a boost with the introduction of the rural reforms in 1978 but eventually these levels flattened out following the introduction of the price subsidies in 1984. The price reforms of the early nineties resulted in another spell of boost in optimal effort levels. Prior to that the optimal effort levels remained static following the introduction of increased price subsidy, and the boost in the early nineties suggest that farmers exert more effort under a deregulated price structure. Following the state controls on price which were established in 1998, optimal effort levels increase steadily until 2004 after which they faltten out again. The trends in optimal effort levels are similar for both model 3 and model 9.

With the introduction of the rural reforms in 1978 farmers' welfare level experiences an immediate boost. But after that it remains more or less static until 1993. A series of droughts in the early nineties adversely affected agriculture in China, which is apparently why despite the nineties' price reforms and deregulation of markets the farmers' profits were not as expected resulting in a decline in welfare. With increased level of effort, welfare starts to drop sharply from the early nineties and continues to drop until 1996. Just prior to the introduction of the price regulations the welfare has a sharp increase, but right after the introduction of the most recent regulations farmers' welfare drops again. This reform is followed by a temporary increase in welfare in 1999, after which it drops again.

Our computations show that until the two tier pricing reform was undertaken, farmers welfare was more or less stable with its growth moving around a zero mean. This was the period when the government introduced increased price subsidy (in 1984) and a scheme of subsidies to cereal production (in 1986). This in turns imply that the introduction of flat subsidies during the eighties actually did very little in improving farmers' welfare, and the farmers actually responded more when pricing reforms were introduced and markets were further deregulated.

5.2 Regional level growth in TFP and growth in its incentive component

We use standard Solow residual approach in order to compute the TFP and its growth rate for the regional level for the period 1997-2006. Computation of the regional level A_{inc} requires more information at the regional level. The SYB, CBNS does not report input prices for the regional level, which is why we use available information and (5) in order to compute a series of the term $p(1-\xi\phi)$ in (15) for each region over the period 1997-2006. Only the SYB, CBNS 1997 reports per capita profits of agricultural households, which is why we collect the information on per capita *net income* of rural population (in yuan) from the *people's livelihood* series in the SYB, CBNS. We hold this as a proxy for per capita agricultural profits. We derive the per capita wheat output by dividing the aggregate regional wheat output by the total agricultural labour force. A measure of the term $p(1-\xi\phi)$ for the regional level is then derived using (5).

In order to verify this computation we collect information on the gross value of farming, forestry, animal husbandry and fishing output, which is in 100 million yuans for each region over the period 1997-2006. This measure is a crude proxy for the term pQ, where Q denotes aggregate regional output of all agricultural activity. We divide this number by the agricultural labour force in order to derive a crude measure of the term pq in (5), i.e. a measure of the per capita gross value of agricultural output. The ratio of the per capita agricultural profits and the per capita gross value of agricultural output gives us the term $(1-\xi\phi)$ for the regional level. We derive a measure of the price level at the regional level by dividing the term pq by the per capita output of all agricultural activity (the total agricultural output in 1000 tons is available from the Agriculture series in SYB, CBNS). We use the computed price series and the series of computed $(1-\xi\phi)$ we generate a series of $p(1-\xi\phi)$. This is a measure of this term at the total agricultural level, while the former computation was for wheat production. We find that these two series have similar trends and there is a difference in their levels. We use the first computed series for simulating the series of A_{inc} at the regional level.

The growth in regional level TFP and the growth in its incentive component for model 3 and model 9 are presented in figure 8 and figure 9 in appendix B. The simulations are for the most recent reform period (the grain self-sufficiency regime), and for both models the trends are similar. For all 30 regions in the sample there is literally no growth in the incentive component. Although the growth in TFP is volatile, the rate is mostly in the negative margins except for regions Anhui, Beijing and Yunnan. There is positive growth in TFP in 2004 for 12 out of the 30 regions (e.g. Anhui, Beijing, Fujian, Inner Mongolia, Gansu, Guangdong, Shanghai and some others). Some positive growth (on an average) in the incentive component of TFP can be observed in Chongqing, Fujian, Guangxi, Guizhou, Hunan, Jiangxi, Liaoning, Shaanxi, Sichuan, Tibet and Xiangjin.

The regional level simulations justifies the key findings of this paper well. They show that with the introduction of the price regulations, the government has destroyed the growth in the incentive component of TFP at the regional level as well as the country-wide level. This has resulted in an average negative growth of TFP, which in turns resulted in a continuous decline in wheat production both at the regional level and the country-wide level.

6 Concluding Remarks

Many important studies which were undertaken before 1998 (e.g. Halbrendt and Gempesaw, 1990, Harrold, 1992 and Lin, 1992) report that the agricultural reforms in China that were introduced until 1991 have performed their aim of generating rapid economic growth on the basis of efficiency gains. Harrold (1992) for instance finds that the subsidies introduced in 1984 resulted in a 13.1% growth in gross output value and 6.8% growth in agricultural output, which at the start of the rural reform were 10.7% and 6%, respectively. In the same study Harrold (1992) reports that due to these reforms there was an overall increase in welfare which in turns resulted in a decline in rural poverty levels. But China has suffered a major decline in the annual growth rate of wheat production following the first phase of rural reforms. While the average growth rate of wheat production was 7.32% for the decade 1978-1987, the same for the decade 1988-1997 was only 2.08% (see Pingali and Heisey, 2001 for details). Allegedly, this low growth rate in wheat production motivated the government to take back the control over agricultural prices.

In this study, we examine the most recent agricultural reforms in China at tandem with the first two phases of rural reforms. This enables us to clearly identify which reforms did exactly what. Our results suggest that neither the rural reforms of 1978 nor the eighties' introduction of flat subsidies generated enough incentives for farmers to increase effort in production. Neither of these reforms were associated with major changes in farmers' welfare. It was the price reforms of the early nineties (eventually leading the market towards greater degree of liberalization) that provided enough incentives to exert more effort towards achieveing a higher level of productivity in wheat production. Higher effort levels in this period apparently resulted in a lower level of welfare because the resulting profits were not high enough to offset the adverse effect of effort on farmers' utility. This is where we find the importance of the role weather shocks (the series of droughts of the early nineties) and the Asian financial crisis played in reducing farmers' profits. The positive impact of the pricing reform was therefore overshadowed by random shocks to the economy.

We find some welfare improvement which immediately followed the re-introduction of state control over agricultural prices. Overall the series of agricultural reforms introduced in China in the nineties shows to have had the most important impact on wheat farmers' productivity and welfare. These findings imply that the future agricultural reforms in China need to focus on their potential impact on the welfare of farmers, something which can be achieved through the introduction of a more deregulated market structure where the government would have minimum control over the pricing of agricultural inputs and output.

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Appendix A: Tables

Table 1: Summary statistics for regional level data (30 regions, 1997-2006)

Variable	Description	Mean	St. Dev	Min	Max
Output	Total yield of wheat (1000 tons)	1449.37	3260.82	0.030	17271.96
Labour	Agricultural employment (10000 persons)	282.70	548.91	0.855	5193.69
Machinery	Total power of agricultural machinery (10000 kw)	521.24	984.02	2.507	4854.93
Land	Total area of land sown for wheat (10000 Hectares)	384.92	957.03	0.012	11771.28
Fertilizer	Total quantity of chemical fertilizer (10000 tons)	39.28	68.32	0.270	332.26

Table 2: Summary statistics for national level data (time series, 1978-2007)

Variable	Description	Mean	St. Dev	Min	Max
Output	Total yield of wheat (1000 tons)	23774.16	5721.55	15602.55	33835.04
Labour	Agricultural employment (millions)	0.30	0.06	0.20	0.42
Machinery	Total power of agricultural machinery (10000 kw)	8851.06	2984.16	3450.05	14924.07
Land	Total area of land sown for wheat (1000 Hectares)	7454.94	2032.04	3819.56	10012.99
Fertilizer	Total quantity of chemical fertilizer (1000 tons)	8731.71	2617.05	3919.59	13830.86

Table 4: Summary of Wald test for CRTS hypothesis.

Model	Test Statistic	Critical value $\alpha = 0.05$	Critical value $\alpha = 0.01$	Decision
1	8.788	3.876	6.731	Reject Null
2	3.780	3.876	6.731	Accept Null
3	3.797	3.877	6.734	Accept Null
4	0.183	3.873	6.721	Accept Null
5	2.036	3.873	6.721	Accept Null
6	7.122	3.874	6.722	Reject Null
7	6.912	3.874	6.719	Reject Null
8	2.357	3.874	6.724	Accept Null
9	1.506	3.876	6.731	Accept Null
10	1.881	3.877	6.734	Accept Null

Table 3: Summary of panel estimation and diagnostic tests

Model	Cross Section	Period	Cov. method*	Rand. eff. method**	Constant [p-value]	γ_1 [p-value]	γ_2 [p-value]	γ_3 [p-value]	γ_4 [p-value]	CRTS//	$\overline{R}^2$	RESET^	Fixed Effects$	Rand eff. consistency$^{\varpi}$
1	None	None	WCS	S-A	0.393	-0.220	0.375	1.015	-0.107	No	0.978	No		
					[0.017]	[0.000]	[0.033]	[0.049]	[0.000]					
2	Fixed	None	WCS	S-A	0.740	0.696	-0.227	0.455	0.137	Yes	0.991	Yes	CS	
					[0.039]	[0.102]	[0.210]	[0.059]	[0.191]					
3	Fixed	Fixed	WCS	S-A	0.963	-0.276	0.591	0.433	0.173	Yes	0.994	No	CS, P	
					[0.004]	[0.053]	[0.041]	[0.038]	[0.082]				CS & P	
4	Random	None	Ordinary	W-K	0.909	0.477	-0.135	0.555	0.129	Yes	0.899	Yes		CS
					[0.050]	[0.000]	[0.213]	[0.000]	[0.225]					not consistent
5	Random	Random	Ordinary	W-K	0.997	-0.254	0.531	0.492	0.225	Yes	0.854	Yes		P consistent
					[0.017]	[0.090]	[0.000]	[0.000]	[0.089]					CS not consistent
6	None	Fixed	WCS	S-A	0.412	-0.217	0.365	1.020	-0.108	No	0.979	No	P	
					[0.007]	[0.000]	[0.000]	[0.000]	[0.003]					
7	None	Random	WCS	S-A	0.404	-0.218	0.369	1.018	-0.108	No	0.978	No		
					[0.014]	[0.000]	[0.000]	[0.000]	[0.000]					
8	Random	Fixed	Ordinary	W-K	0.989	-0.325	0.599	0.485	0.158	Yes	0.930	Yes	P	CS
					[0.004]	[0.034]	[0.000]	[0.000]	[0.079]					not consistent
9	Fixed	Random	Ordinary	W-K	0.964	-0.190	0.511	0.439	0.168	Yes	0.993	No	CS	P consistent
					[0.007]	[0.245]	[0.000]	[0.000]	[0.065]					
10	Fixed	Fixed	Ordinary	S-A	0.963	-0.276	0.591	0.433	0.173	Yes	0.993	Yes	CS, P	
					[0.008]	[0.097]	[0.000]	[0.000]	[0.058]				CS & P	

*WCS refers to White Cross Section.

**S-A refers to Swamy-Arora method, and W-K refers to Wansbeek-Kapteyn method.

^No implies no misspecification, Yes implies misspecification, based on RESET test.

//No implies rejection of CRTS hypothesis, Yes implies acceptance of CRTS hypothesis, based on Wald test.

$ CS and P refers to cross section and period fixed effects significance, respectively, based on Fixed effects redundancy test.

ϖ CS and P refers to cross section and period random effects, respectively, based on Correlated Random effects test.

Null hypothesis is constant returns to scale, i.e. $\gamma_1 + \gamma_2 + \gamma_3 + \gamma_4 = 1$.

Table 5: Pinned down parameter values for model 3 and model 9.

Model	a_1	a_2	a_3	a_4	σ	ξ	a_0
3	0.985	0.007	0.005	0.002	0.099	0.348	1.00
9	0.950	0.020	0.020	0.010	0.098	0.351	0.99

Table 6a: Summary of redundant fixed effects test.

Model	Cross section FE* test statistic [p-value]	Period FE test statistic [p-value]	Cross section & Period FE test statistic [p-value]
2	15.24 [0.000]		
3	25.22 [0.000]	15.50 [0.000]	21.01 [0.000]
8		15.57 [0.000]	
9	25.022 [0.000]		
10	25.22 [0.000]	15.50 [0.000]	21.01 [0.000]

* FE denotes Fixed Effects.

Table 6b: Summary of correlated random effects test.

Model	Cross section RE* test statistic [p-value]	Period RE test statistic [p-value]	Cross section & Period RE test statistic [p-value]
4	23.92 [0.000]		
5	22.43 [0.000]	5.91 [0.206]	29.50 [0.000]
8	25.97 [0.000]		
9		7.56 [0.109]	

* RE denotes Random Effects.

Appendix B: Figures.

Figure 1a.1: Wheat production in 1000 tons, 1978-2007

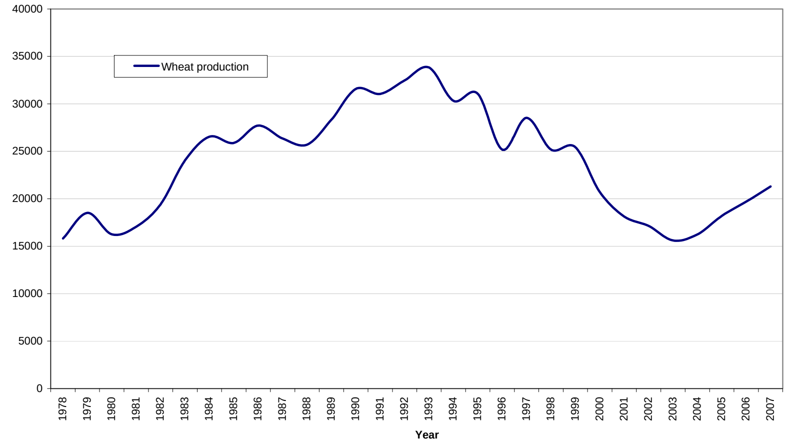

Figure 1a.2: Total Sown Area (in 1000 Hectares) of wheat, 1978-2007

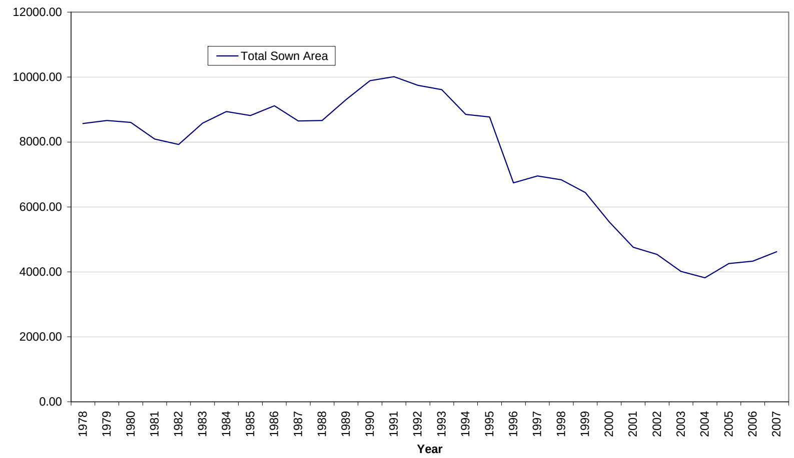

Figure 1a.3: Agricultural employment (in millions), 1978-2007

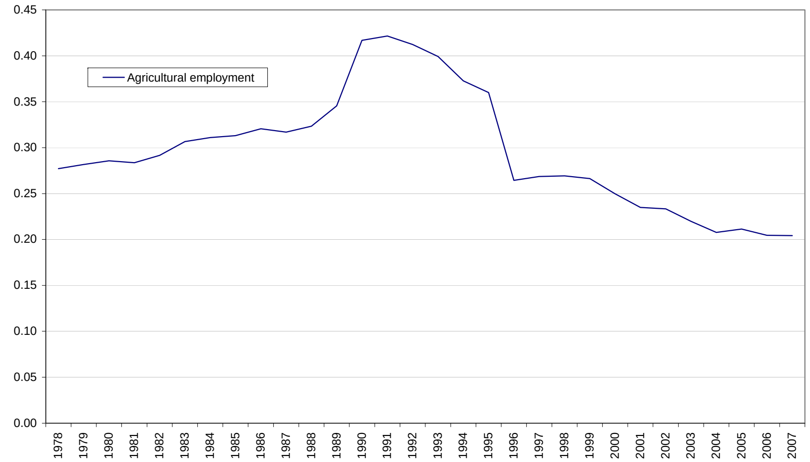

Figure 1a.4: Chemical fertilizer in agriculture (in 10000 tons), 1978-2007

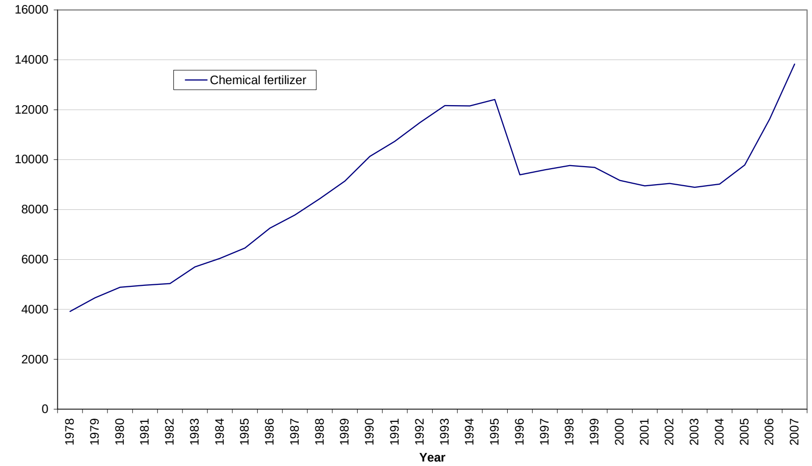

Figure 1a.5: Total power of agricultural machinery (in 10000 kw), 1978-2007

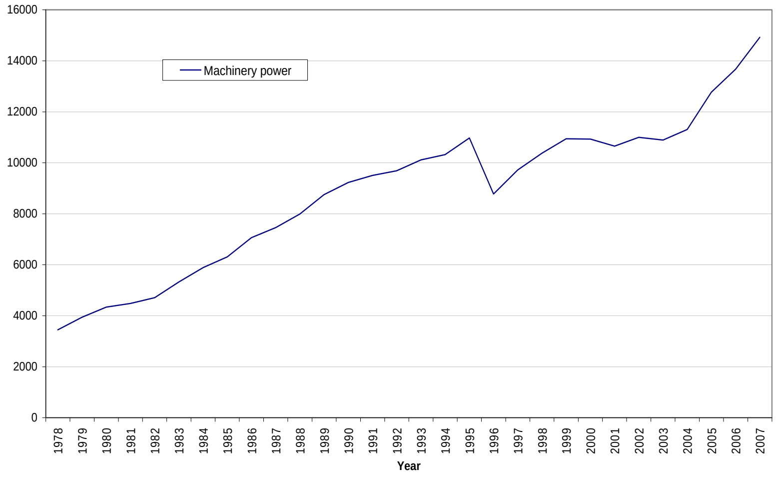

Figure 1b.1: Wheat price index, 1978-2007

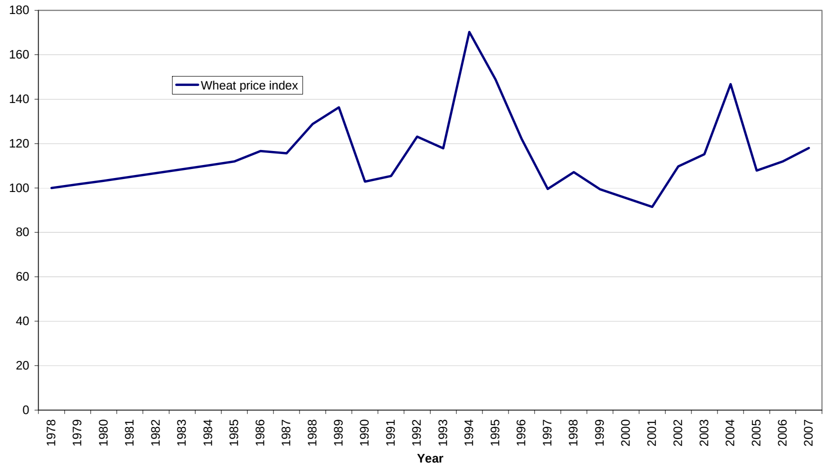

Figure 1b.2: Land rental index, 1978-2007

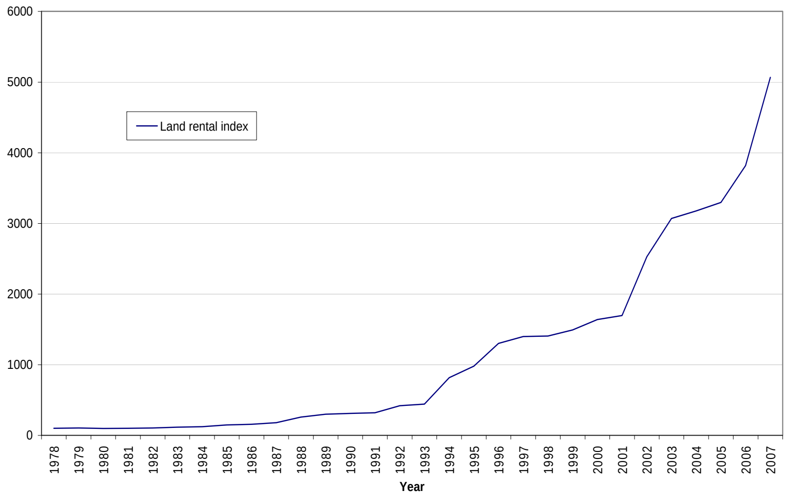

Figure 1b.3: Wage index, 1978-2007

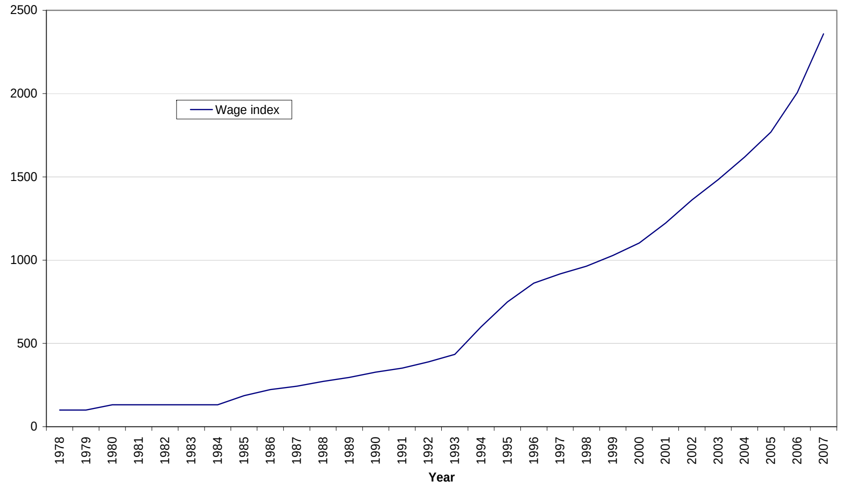

Figure 1b.4: Fertilizer price index, 1978-2007

Figure 1b.5: Machinery price index, 1978-2007

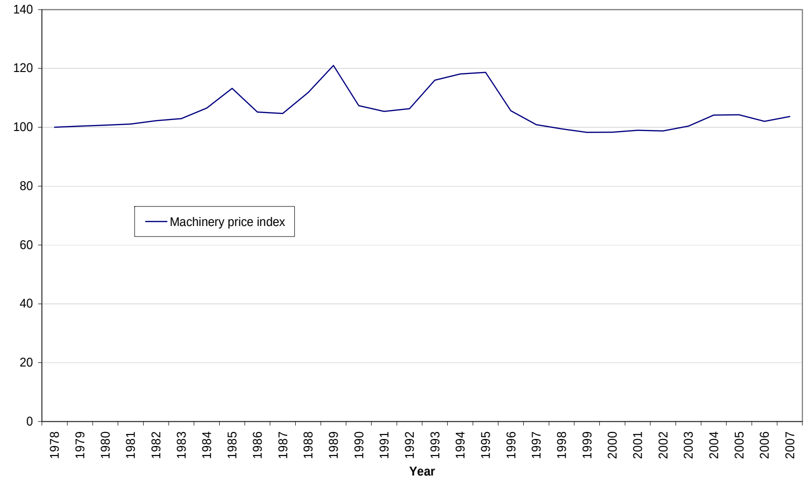

Figure 1b.6: Profit index, 1978-2007

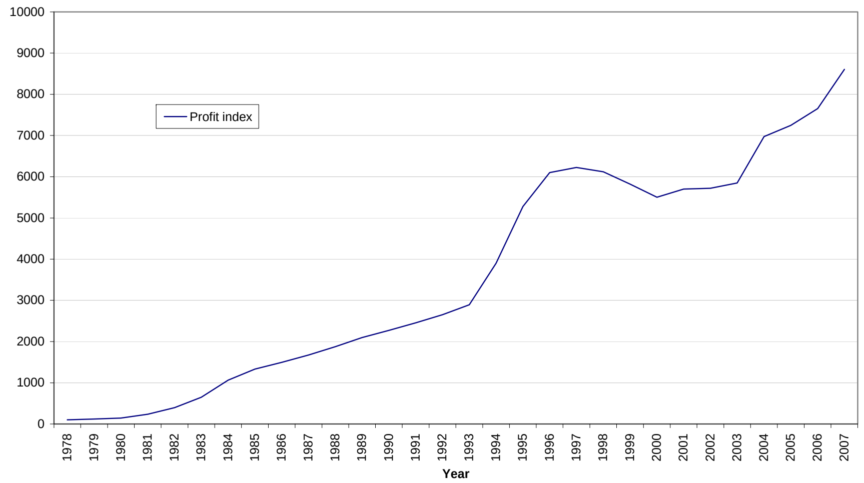

Figure 4a: Welfare Index for Model 3

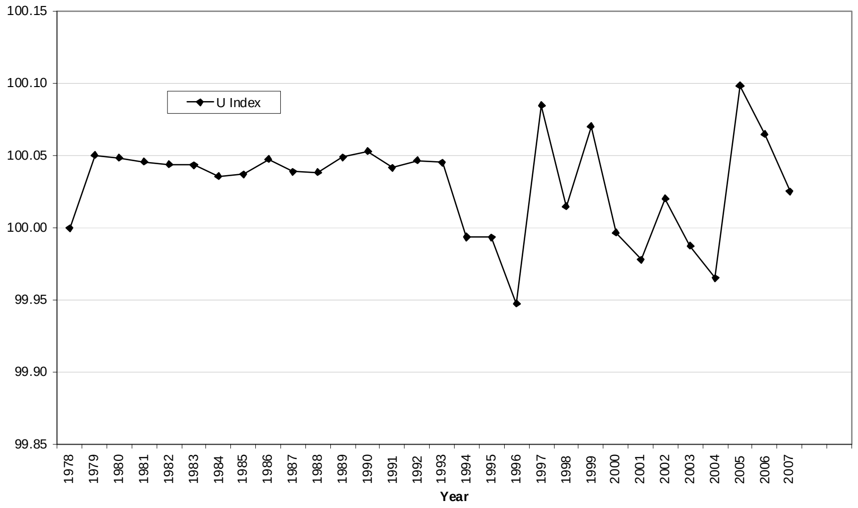

Figure 4b: Welfare Growth for Model 3

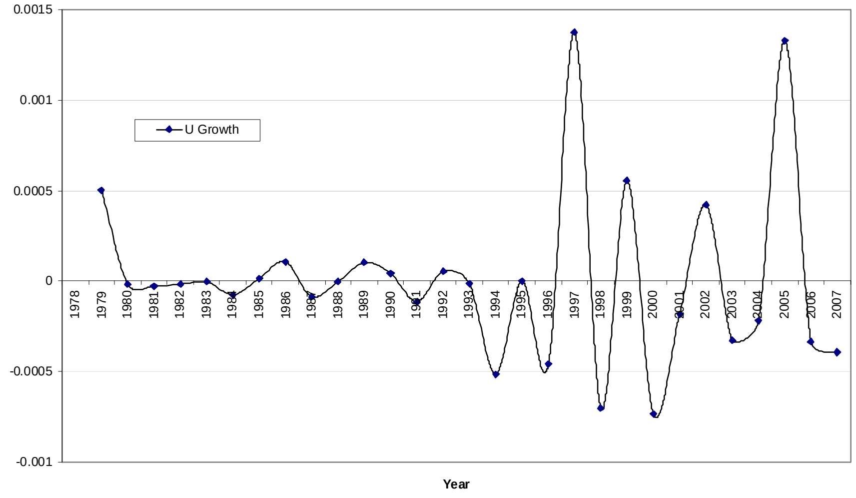

Figure 5a: Optimal effort level for N (Model 3)

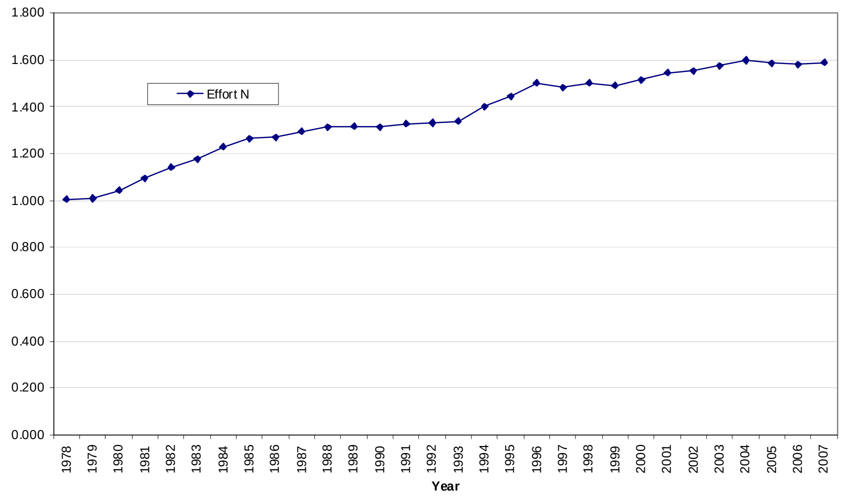

Figure 5b: Optimal effort level for M (Model 3)

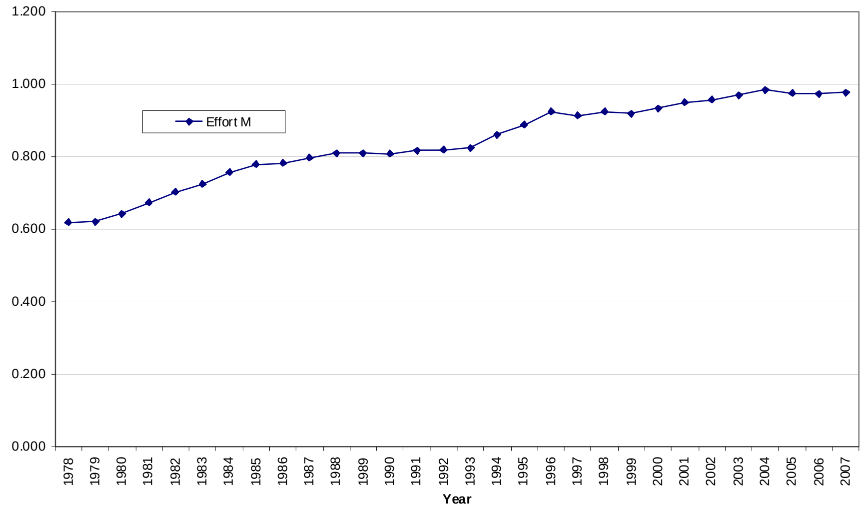

Figure 6a: Welfare Index for Model 9

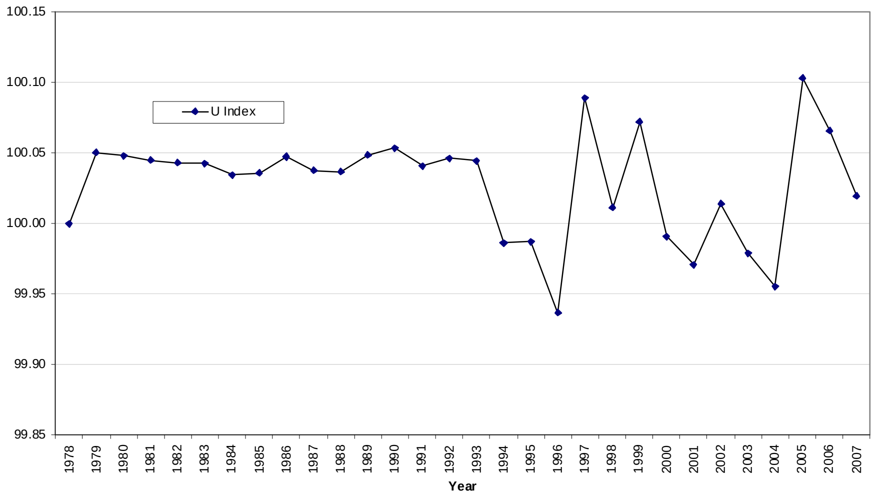

Figure 6b: Welfare growth for Model 9

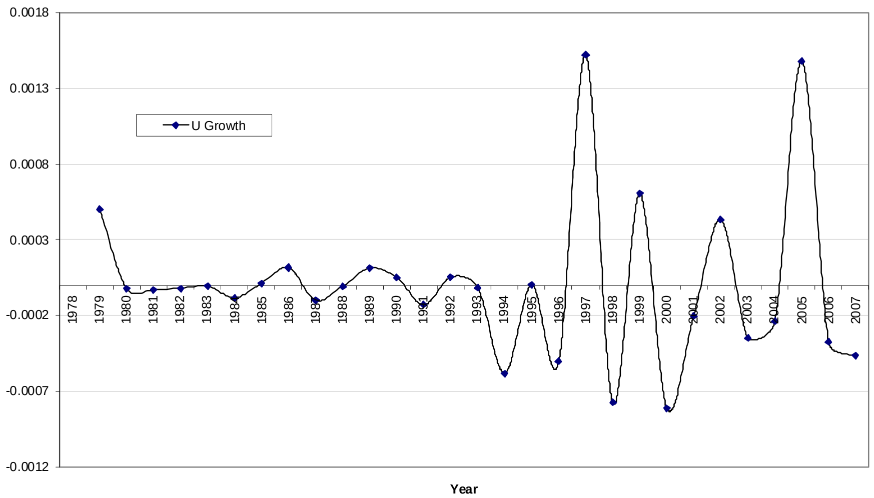

Figure 7a: Optimal effort level for N (Model 9)

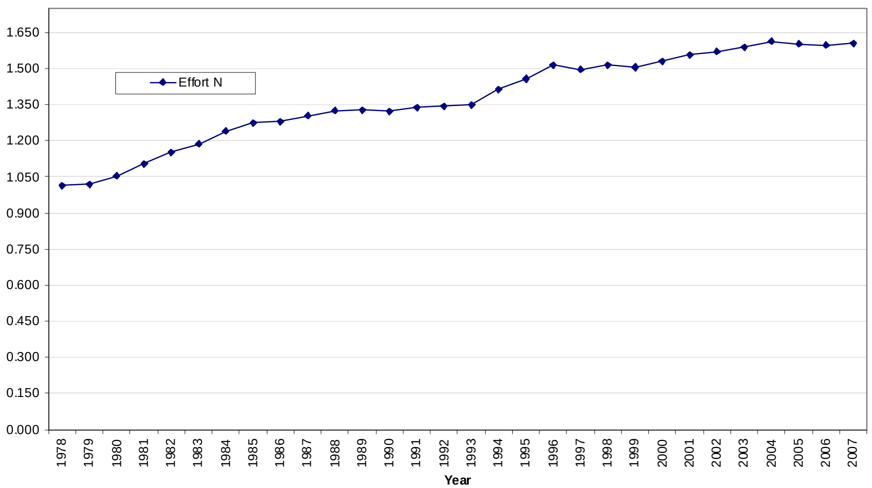

Figure 7b: Optimal effort level for M (Model 9)

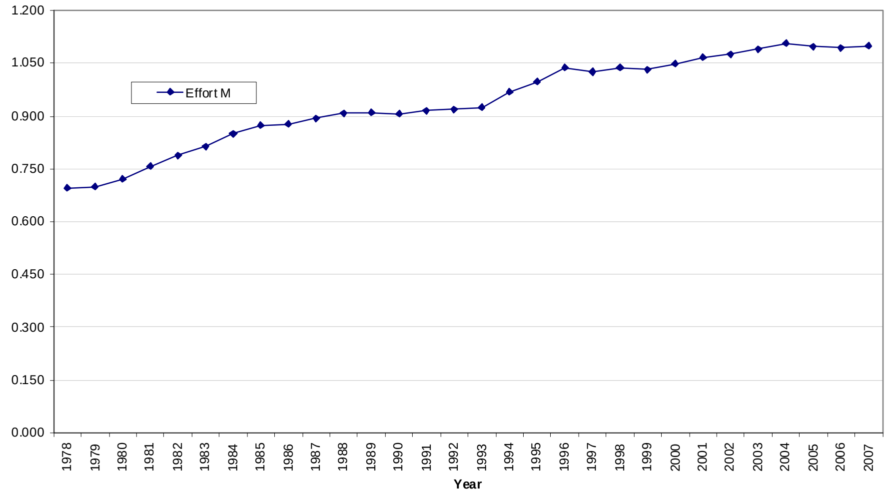

Figure 3b: Growth in TFP (A) and growth in the incentive component of TFP (Ainc) for Model 9

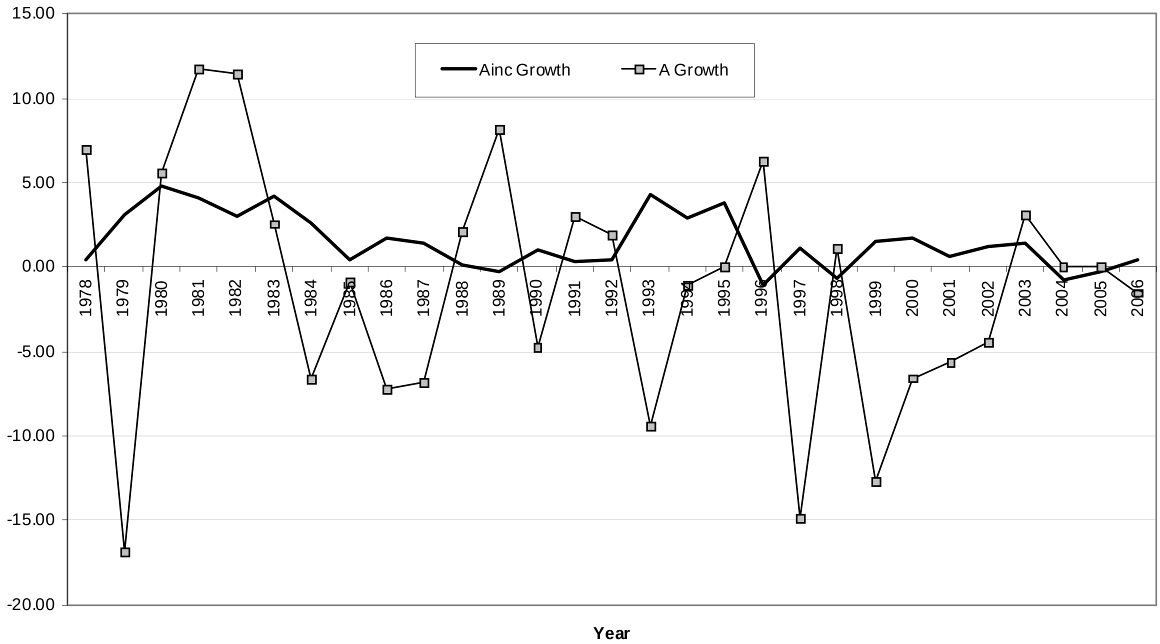

Figure 3a: Growth in TFP (A) and growth in the incentive component of TFP (Ainc) for Model 3

Figure 2a: TFP Index (A) and the incentive component of TFP (Ainc) for Model 3

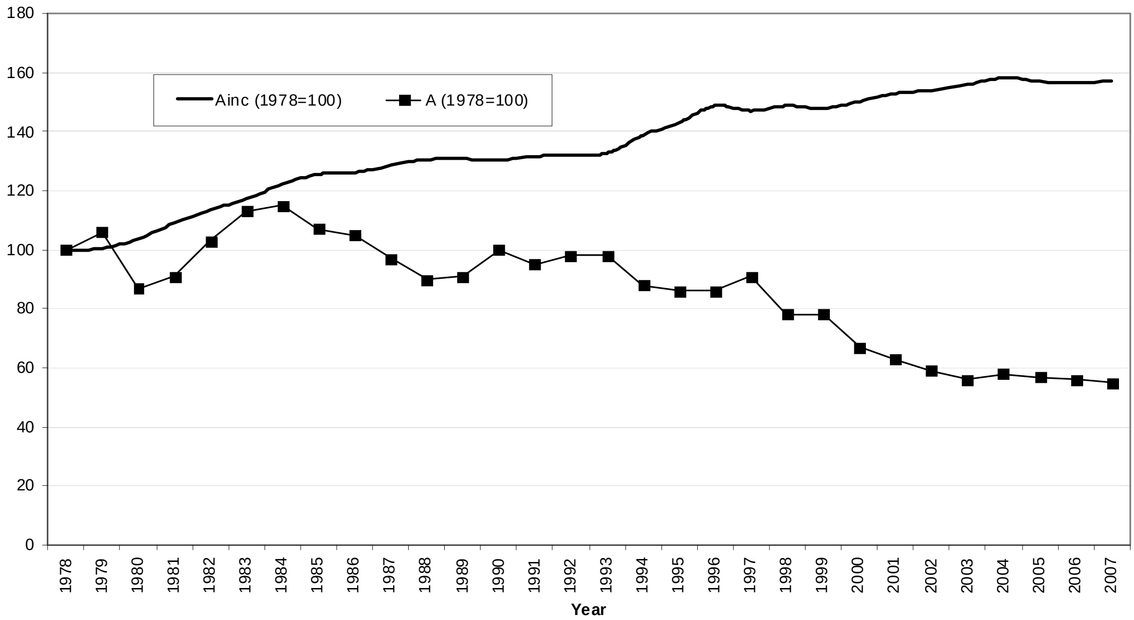

Figure 2b: TFP Index (A) and the incentive component of TFP (Ainc) for Model 9

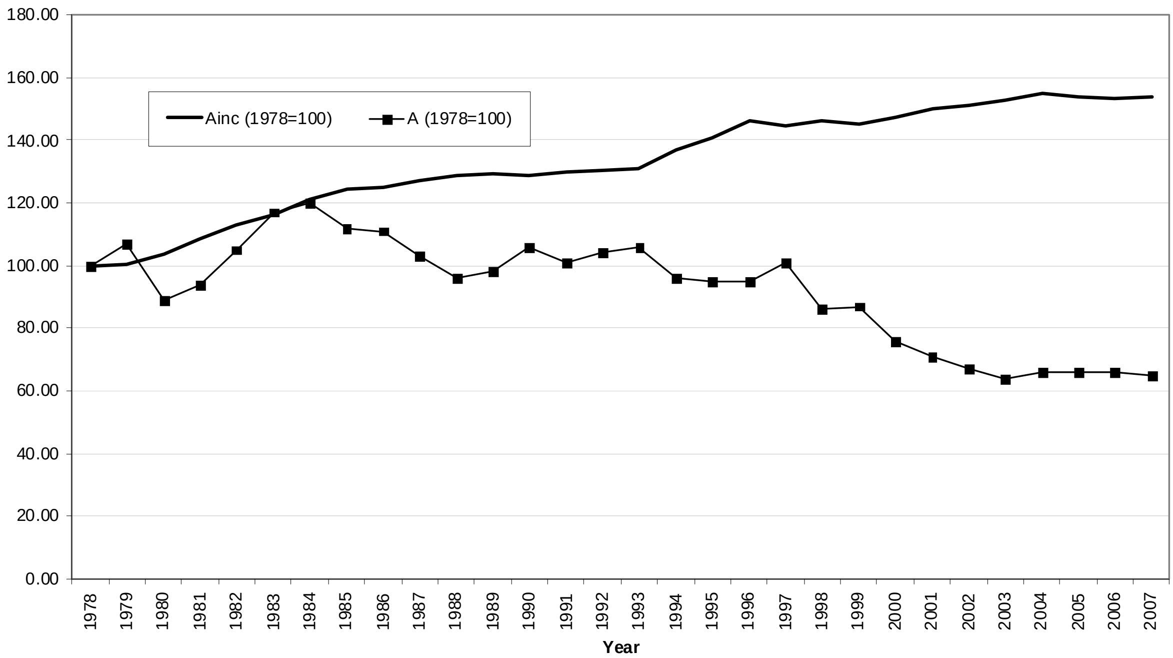

Figure 8: Regional level growth in TFP and growth in incentive component of TFP (1997-2006) for Model 3.

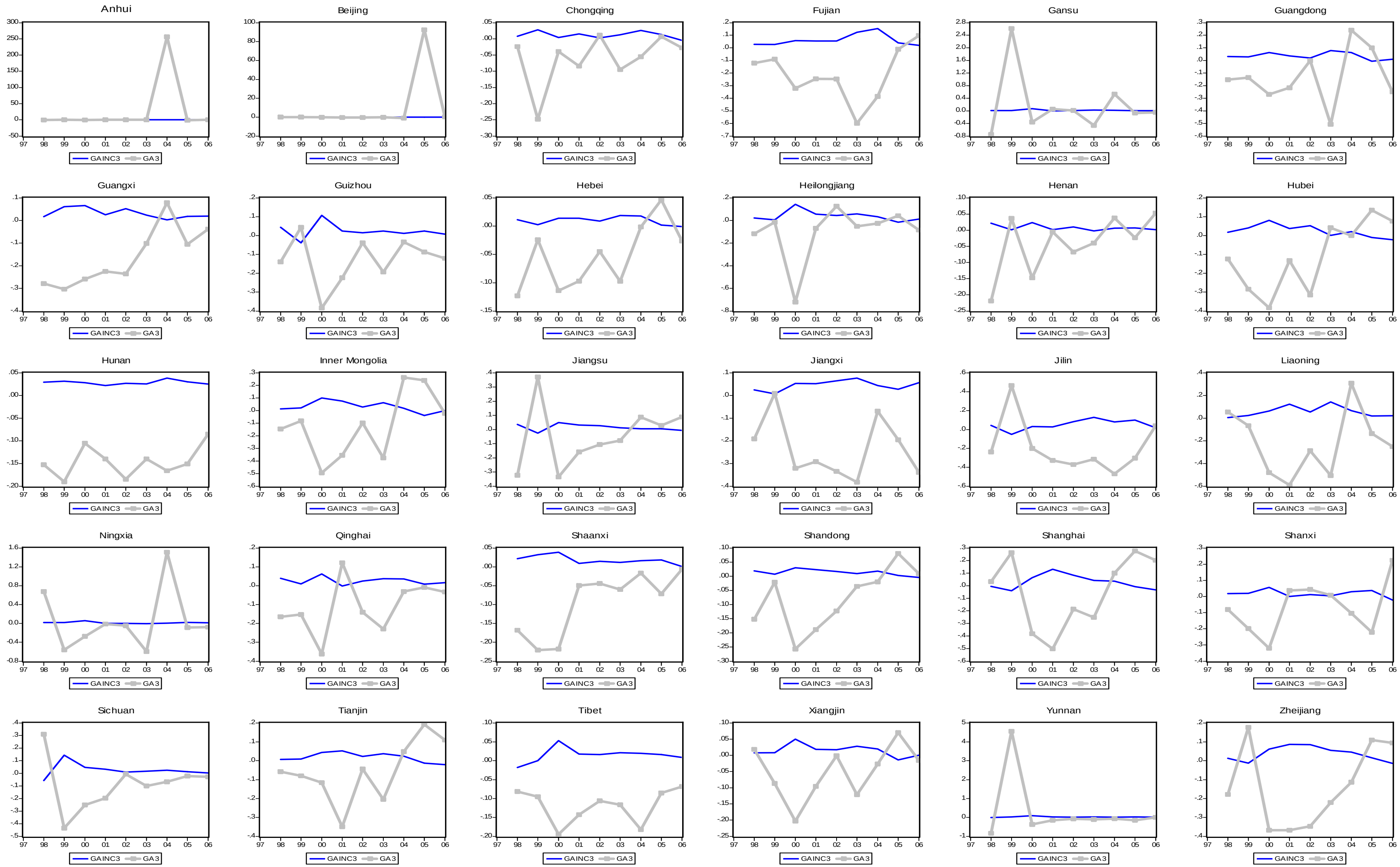

Figure 9: Regional level growth in TFP and growth in incentive component of TFP (1997-2006) for Model 9.