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Policy Reforms and Incentives in Rice Production in Bangladesh

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Abstract

We estimate an institutional production function to capture incentive induced growth in total factor productivity (TFP) of rice production in Bangladesh. The incentive component of TFP assists in explaining how farmers responded to the changes in incentives which were introduced during the major policy reforms undertaken in the 1980s and the 1990s.

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1 Introduction

In this paper we examine the growth in Total Factor Productivity (TFP) of rice production in Bangladesh and the growth in the incentive component of this TFP over three major agricultural policy regimes, namely, the input subsidy regime, the output price support regime, and the liberalized regime[1]. We investigate the incentive-induced growth in TFP where the incentive to exert more effort is a result of market reforms. We capture the link between incentives and market reforms in a simple framework that models farmers' optimal response to changes in policy and institutions.

We follow the approach as in Hayami and Ruttan (1985), which McMillan, Whalley and Zhu (1989) and Zhang and Carter (1997) explore to study agricultural productivity growth in China, and Kompas (2005) applies to study the Vietnamese agriculture. Typically in transitional economies factor and product prices increase at different rates with market reforms. We characterize this process through a weighted cost-share parameter of rice production: the ratio of average factor to product prices. We compute this parameter over the three policy regimes. As is true for most transitional economies, 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 an effort level that is optimal. We use the farmers' optimal effort function in order to transform a technical rice production function into what we call an *institutional* production function that captures farmers' optimal response to changes in institutions and policy. We estimate this function using cross sectional data of 23 major rice producing districts of Bangladesh. We use the estimated factor share parameters, other parameters of the model, and time series data of factor and product prices to simulate the time path of TFP and its incentive component over the three policy regimes, which in turns enables us to compare the TFP growth and the growth in the incentive component of this TFP.

We find that rice farmers in Bangladesh, in general, respond to incentives, and deregulated markets generally encourage farmers to exert more effort. Our study clearly shows that a major source of productivity growth in Bangladesh agriculture is the incentive effects resulting from market reforms.

2 The Context

We consult various issues of the *Five-Year Plan* documents of the Ministry of Finance and Planning of the Government of Bangladesh in order to present a summary of the major agricultural policy reforms in Bangladesh. Until 1982, farmers received subsidies to material inputs (but no subsidies to wage) and in the wholesale agricultural market the highest quantity of rice they could sell in one transaction was fixed. This phase of very low agricultural output growth, mainly due to a low level of technology, can be characterized as one of traditional means of cultivation with heavy dependence on weather and land fertility. This encouraged the government to adopt a new input technology package that included high yield seeds and hybrid fertilizers. In addition, the government introduced the output price support policy and abolished the quantity rationing system and direct subsidies to material inputs. The main motivation behind these reforms was giving a boost to the domestic agricultural production and the factor productivity.

[1] If rice production function is $Q = Af(X_1, X_2, ..., X_n)$, where Q denotes total output of rice, $X_i s, i = 1, 2, ..., n$ denote the quantities of n inputs used in producing Q, Total Factor Productivity (TFP) of rice production, denoted by A, is the portion of rice 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 rice production.

The government continued with the output price support policy until the late eighties. One of the main reasons behind continuing with this policy was that the rate of increase in the price of imported fertilizers and improved seeds was persistently higher than the rate of increase in the market price of rice. This difference, allegedly, was mainly due to a heavily regulated channel of the distribution of inputs. Given such issues in the distribution of inputs, having only the output price support policy to boost agricultural production is generally ineffective. With a view to improving the channels of the distribution of inputs, the government decided to move towards deregulation.

Starting from 1990, the agricultural policy reforms undertaken in Bangladesh were mainly regulatory reforms of the input supply chain and widening of the genetic base of crops. These included liberalization of the input supply chains, crop diversification and extended research on rice production. Instead of mono rice cropping, the government encouraged multi rice cropping and round the year cropping of a wider variety of rice[2]. Other major reforms included the privatization of supply of fertilizers and high yield seeds, management and distribution related reforms of fertilizer and irrigation equipment, and a reform of the output price support policy. On the supply side, the government introduced a policy that allows private traders to import diesel engines without taxes or restrictions, couple these engines with domestic pumps and pipes, and sell the equipment to farmers for irrigation. The government removed all duties and quotas on power tillers and pesticides. The government also abolished all local as well as regional controls over fertilizer distribution and sales. While such policy reforms stimulated private investment, other changes in government programs related to agriculture also boosted public investment in agriculture.

In this paper we categorize these major agricultural policy reforms in Bangladesh in three policy regimes over the period 1979-1998, namely, the input subsidy regime (1979-1981), the output price support regime (1982-1989), and the liberalized regime (1990-1998). We estimate the rice production function using cross sectional data of 23 major rice producing districts of Bangladesh in a given year, 1997. We then use the estimated parameters from this model to simulate a TFP index and an index of the incentive component of TFP in rice production over the sample period 1979-1998. This allows us to investigate the movement in TFP growth and growth in the incentive component of TFP over the three policy regimes, which in turns explains how farmers have reacted to changes in policy.

3 The Model

We assume that the production of rice requires four inputs: effective contribution of labour, land, fertilizer and high yield seeds. The level of effort of a farmer is denoted by ε, so that in a model with N farmers, εN is the effective contribution of labour to output, measured in efficiency units[3]. 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 rice is:

$$Q = a_0 (\varepsilon N)^{a_1} (L)^{a_2} (S)^{a_3} (F)^{a_4} \tag{1}$$

[2]Traditionally, the rice cropping season in Bangladesh is between March to September, i.e. the monsoon season. During the nineties the government introduced new hybrids which can be cultivated throughout the year.

[3]In this model the variable *effort* includes everything that determines the quality of the farmers' labour as well as the willingness to exert more effort as a result of enhanced incentives to earn more by producing more.

where Q, L, S and F denote total output of rice, land area under cultivation of rice, high yield seeds and fertilizer used in producing rice. In per capita terms, the production function is

$$q = a_0 \varepsilon^{a_1} l^{a_2} s^{a_3} f^{a_4} \tag{2}$$

Let m denote farm income, such that

$$m = pq \tag{3}$$

where p is the market price of rice. Farmers choose the least cost combination of inputs. The total cost function is given by:

$$TC = \xi \prod_i w_i^{a_i} Q \tag{4}$$

where $\xi > 0$ is a constant, and $w_i, i = 1, 2, 3, 4$, denotes the price of input i. With the average real input price $\Gamma(w) = \prod_i w_i^{a_i}$, the cost of production per farmer is:

$$C = \xi \Gamma(w) q \tag{5}$$

Let $\omega \equiv \frac{\Gamma(w)}{p}$, which is the ratio of the observed average input to product prices. With (3), the farmer's profit function becomes:

$$\pi = pq(1 - \xi\omega) \tag{6}$$

Farmers utility is defined over profits and effort, and they like the profits but dislike the effort of hard work. Their utility function is:

$$u(\pi, \varepsilon) = \pi - \frac{\varepsilon^\theta}{\theta\phi} \tag{7}$$

with $\phi > 0$, $\theta > 1$. The effort disutility coefficient, θ, is analogous to the coefficient of risk aversion. Substituting from (2) and (6), we can write the farmers' utility maximization problem as:

$$\max_{\varepsilon} u(\varepsilon) = pa_0 \varepsilon^{a_1} l^{a_2} s^{a_3} f^{a_4} (1 - \xi\omega) - \frac{\varepsilon^\theta}{\phi\theta} \tag{8}$$

The optimal value of effort level satisfies

$$(\varepsilon^*)^\nu = [\phi p (1 - \xi\omega) a_0 a_1 l^{a_2} s^{a_3} f^{a_4}] \tag{9}$$

where $\nu = (\theta - a_1)$. Notice here that the optimal effort level depends on, among others, the parameters of the technical production function, (1), the output price of rice, the input prices and the parameter ξ which is related to the total cost of producing rice. Policy reforms and changes in markets and institutions are reflected in the output price of rice and the input prices, and observing these prices the farmers choose their optimal effort level. We substitute (9) 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:

$$Q = \left[a_0^{\frac{\theta}{\nu}} \{a_1 p \phi (1 - \xi\omega)\}^{\frac{a_1}{\nu}} \right] N^{\gamma_1} L^{\gamma_2} S^{\gamma_3} F^{\gamma_4} \tag{10}$$

where $\gamma_1 = \frac{a_1(\theta-1)}{\nu}, \gamma_2 = \frac{a_2\theta}{\nu}, \gamma_3 = \frac{a_3\theta}{\nu}$ and $\gamma_4 = \frac{a_4\theta}{\nu}$. We define $A \equiv a_0^{\frac{\theta}{\nu}} \{a_1 p\phi (1 - \xi\omega)\}^{\frac{a_1}{\nu}}$ as the total factor productivity (TFP) coefficient of rice production. The institutional production function, (10), captures farmers' optimal response to institutional arrangements and the government's policy reforms through the changes in output price, p, and the changes in ratio of observed average input to product prices, ω. Since these two affect the TFP coefficient in the institutional production function, changes in the TFP captures farmers' optimal response to changes in policy and institutions.

With observable data, we estimate the institutional production function, (10). We use the CRTS assumption, estimated $\gamma_\iota s, \iota = 1, 2, 3, 4$, and $\nu = (\theta - a_1)$ in order to pin down $a_i, i = 1, 2, 3, 4$, and θ. We then use time series data on output price and input prices in order to compute ω and pin down ξ. We decompose TFP from (10) into two components: the first component accounts for the incentive effects as captured by the optimal effort level, or

$$A_{inc} = \left[p\left(1 - \xi\omega\right)\right]^{\frac{a_1}{\nu}} \tag{11}$$

and the second component

$$A_{other} = \left[\phi^{a_1} a_1^{a_1} a_0^{\theta}\right]^{\frac{1}{\nu}} \tag{12}$$

is an unexplained residual reflecting the influence of a host of other factors, which are not explicitly modelled. Although effort is not observable, empirical estimation of (1) and (10) is actually very different, and so are the $a_i s$ and $\gamma_\iota s$. We have already shown that because of the effort disutility coefficient θ and the share parameter a_1, $a_i s$ and $\gamma_\iota s$ are different. In (10), we have substituted out the effort variable with farmers' optimal effort level. This enables one to redefine the TFP coefficient and then decompose it into two components as in (11) and (12). If one estimates the technical production function with obervable data, one would ignore farmers' effort and the optimal effort response to changes in policy and institutions, and the TFP coefficient a_0 would simply be a constant which cannot be decomposed into incentive and unexplained components. The key purpose of this paper is to compare the growth in TFP and the growth in the incentive component of the TFP, for which the institutional production function is the specification that we will estimate[4].

4 Data and Estimation

We use cross sectional data of 23 major rice producing districts of Bangladesh in a normal cropping year, 1997, (i.e. no floods or other shocks) in order to estimate (10). We have collected these data from the *Yearbook of Agricultural Statistics of Bangladesh*, a publication of the Bangladesh Bureau of Statistics[5]. The districts have similar cropping intensity. We also collect time series data on country-wide aggregate production of rice, input use and input prices, and the average price of rice from the same source. These data are for the period 1979-1998. We present a data appendix that explains the variables we use. Summary statistics of the cross sectional data is in table 1 in appendix. In figure 1 and figure 2 in appendix we present the time series data.

We present the results from Ordinary Least Squares estimation of the institutional production function in appendix table 2. The estimated share coefficients of labour, land, seeds and fertilizer

[4]In this paper, we only simulate A and A_{inc} in order to compare their growth over the three policy regimes. Simulating A_{other} is not a purpose of this paper (since it tells nothing about the incentive-induced growth in TFP). However, one can easily compute A_{other} since $A_{other} = \frac{A}{A_{inc}}$.

[5]The other sources of agricultural data in Bangladesh are the *Sustainable Development Network of Bangladesh (SDNBD)* and the Agricultural Statistical Yearbook of Bangladesh from the *Ministry of Agriculture*, both of which are available online, and both use our data source.

are $0.223, 0.455, 0.176$ and 0.153, respectively, and these are statistically significant at 5% level. Together with the estimates of $\gamma_{\iota}s$, we use the 5 equations $\gamma_1 = \frac{a_1(\theta-1)}{\theta-a_1}, \gamma_2 = \frac{a_2\theta}{\theta-a_1}, \gamma_3 = \frac{a_3\theta}{\theta-a_1}, \gamma_4 = \frac{a_4\theta}{\theta-a_1}$ and $\sum_{i=1}^{4} a_i = 1$ in order to pin down $a_1 = 0.42, a_2 = 0.33, a_3 = 0.12, a_4 = 0.11$ and $\theta = 1.611$. With the time series data on input prices, we compute series of ω, and using the time series data and ω, we pin down $\xi = 0.037$.

We perform a number of diagnostic tests, and their summary is provided in appendix. All tests of heteroscedasticity produced low values of the test statistics, and therefore we accept the null hypothesis of homoscedasticity in the distribution of residuals. We conduct the Ramsey's standard test of specification error (i.e. the RESET). The test statistic for RESET is based on R-squared values of the auxiliary and unrestricted regression models. All tests of Ramsey's RESET indicate that the hypothesis of no misspecification of the model could not be rejected at 5% level of significance. We test the normality of the distribution of residuals using the standard Jarque-Bera (JB) test, where we accept the normality assumption of the distribution of the residuals at 1% level.

5 Total Factor Productivity with Policy Reforms

We use the time series data and the estimated share parameters from (10) in order to compute the TFP as Solow residual for each of the years 1979-1998. We then compute the annual growth rate of TFP (i.e. A). We compute the series of incentive component of TFP, given by (11), using the pinned down parameter values of a_1, θ and ξ, the generated series of ω, and the time series data of output price. We then compute its year by year growth rate. We present the time path of TFP and the incentive component of TFP in figure 3, and the time path of their growth rates in figure 4, in appendix.

We find some interesting results. Prior to the output price support policy period of 1982-1989, under highly regulated market for inputs where price of inputs were subsidized, TFP growth rate was negative. During this period, mainly because of the input price subsidy there was no incentives for farmers to improve factor productivity. There was improvement in the growth of TFP during the early phases of the output price support policy regime, when the growth rate achieved a highest (for this regime) of 0.5% in 1984. However, after 1984 the growth rate fell, reached a record minimum (-5.5%) in 1987, and stayed negative until 1990. The output price support policy therefore failed to sustain the favourable impacts of the growth in factor productivity. Policy reforms in the 1990 which made input markets more liberalized and competitive brought in remarkable success. The TFP growth rate became positive at the start of this regime, reached a new peak (2.7%) in 1993, dropped to the negative zone in the following year, started to pick up thereafter and remained positive during the last three years of our sample period.

We also present the time path of the incentive component of TFP in figure 3, and the growth in this component in figure 4. There is clear evidence of incentive induced growth in TFP during the output price support policy regime (peak 6.3% in 1984) and the current liberalized regime (peak 6.02% in 1992). Over the sample period, the growth rate of the incentive component of TFP reached a record minimum of -3.2% in 1983, which could be due to the political unrest in Bangladesh during the early eighties. The negative growth rate (-1.7%) in the incentive component of TFP in 1989 could be due to the heavy flood of 1988 which resulted in huge crop damage. The overall trend of the growth rate in the incentive component of TFP is quite interesting, because it clearly shows that farmers in general respond strongly to policy reforms, and deregulated markets for output and inputs encourage farmers to exert more effort.

When input prices were subsidized and quantity was rationed (until 1982), farmers had no incentive to increase productivity. The growth rate of TFP and the growth rate of its incentive component experienced a boost with the introduction of the output price support policy and the removal of direct subsidies to material inputs. During this phase of policy reforms, agricultural factor markets became relatively more competitive and prices of all inputs experienced high growth (see figure 2). This growth was accompanied by a high growth of incentive-induced productivity. Due to the liberalization of the input markets, which started in 1990, agricultural markets became more competitive which resulted in high growth in TFP and high growth in the incentive component of TFP. During this phase, flat subsidies and direct price support were replaced by more effective incentive devices, such as privatization of fertilizer and seed supply, fiscal waivers on licensing, institutional reforms such as the introduction of transferability of supply licenses (at market determined price), strategic land management schemes and increased volume of agricultural research.

Our results indicate that no matter how informal the agricultural labour market in Bangladesh is, farmers in general respond sensibly to policy reforms that are directed towards generating more incentives for enhanced factor productivity. There is, of course, a component of TFP which our study does not explain. This component can be accounted for unexplained factors that contribute to TFP.

6 Concluding Remarks

We use a simple optimizing model and study empirically rice production in Bangladesh based on an institutional production function which captures not only the standard technical relationship between inputs and output, but also the optimal effort response to the institutional as well as the market arrangements within which farmers work. Assuming that farmers choose their effort levels optimally, we show that one can compute these incentive effects at each stage of the reforms and compare them with the overall change in TFP. We find that decomposing the incentive component of TFP in Bangladesh agriculture assists a great deal in explaining farmers' response to incentives. Our results clearly show that during the most recent phase of policy reforms there has been a steady increase in the incentive component of TFP of rice production in Bangladesh.

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Data Appendix

The rice output data is aggregate rice production data in tonnes, totalling all production of three major hybrids of rice produced in Bangladesh throughout the year, namely, *Aus*, *Aman* and *Boro*. Production of all varieties of these hybrids (local, transplanted and broadcast) are aggregated for total production of a particular category of hybrid, and all production of particular hybrid categories are aggregated for the aggregate district and national production of rice for cross sectional and time series data. Labour is measured as person-days and is obtained by multiplying average person-days per hectare in agriculture by the rice cultivated area divided by 300 days or one standard labour unit in one year. We measure the porportion of land that is used for rice production by deflating land area (in hectares) under rice cultivation by the total land area (in hectares) available for cropping throughout the year. This fraction, both for different districts and for the country-wide level, was used to transform other input variables for per hectare input usage. Seed is calculated from the average use of hybrid seeds (in tonnes) multiplied by the proportion of land under rice cultivation. In this way we get how much seeds are used per hectare. Fertilizer is calculated from the average amounts of major hybrid fertilizer, namely, Urea, TSP, SSP and ASP, used per hectare in rice production. Time series data for price of rice for 1979-1998 is collected from the survey of Bangladesh Rice Research Institute in different years and the database of SDNBD. The price of rice is the average annual wholesale price of popular hybrids, valued in taka (Bangladeshi currency) per mound (a rural unit of measurement of quantity of rice, and 1 mound=40 kg). Chemical fertilizer price and seeds price are in taka per kg. Wage rate is the total of average wage rates (without meal) for male and female workers. The land rental price is the amount of money (in taka) farmers have to give to the land owner for each mound produced in one hectare of land during a cropping season.

Appendix: Tables and figures

Table 1: Summary statistics of district level rice output and inputs (23 districts, 1997)

Variable	Description	Mean (SD)	Min	Max
Output	Rice production in district i (in 000 tonnes)	93.78 (21.77)	2.4	211.66
Land	Area (under rice cropping) in district i (in 000 hectares)	437.88 (16.49)	15.87	621.23
Seed	Improved seeds in district i (in 000 tonnes)	124.04 (22.11)	20.78	299.02
Fertilizer	Fertilizer in district i (in 000 tonnes)	72,054.02 (105.05)	2643.16	1,12,211
Labour	Labour in district i (in 000 work days)	3.48 (0.775)	1.802	6.15

Table 2: OLS estimation results (Dependent variable: $\ln Q$)

Variable	Estimate (s.e.)	p-value
constant	0.377 (0.6703)	0.580
ln(labour)	0.220 (0.1009)	0.042
ln(land)	0.455 (0.0885)	0.000
ln(seeds)	0.176 (0.0600)	0.009
ln(fertilizer)	0.153 (0.0624)	0.024
R-squared	0.9711	
R-squared adjusted	0.9626	
S.E. of estimation	0.2203	

Table 3: Summary of likelihood ratio test for CRTS and the Jarque-Bera test

Null hypothesis	Test statistic	Critical value	Decision
$\gamma_1+\gamma_2+\gamma_3+\gamma_4 = 1$ (CRTS)	4.69	6.6349	Accept null
Normal distribution of OLS residuals	7.7649	9.21	Accept null

Table 4: Heteroscedasticity tests (null hypothesis: Homoscedasticity)

$\begin{pmatrix} u \equiv residual \\ \widehat{Q} \equiv predicted \end{pmatrix}$	χ^2 statistic	Critical χ^2 at 5% level	Decision
u on $\widehat{Q}$	0.221	3.8414	Accept null
u^2 on $\widehat{Q}$	0.199	3.8414	Accept null
u^2 on $ln\widehat{Q}$	0.241	3.8414	Accept null
B-P-G test	6.520	9.4877	Accept null
Harvey test	3.398	9.4877	Accept null
Glejser test	5.136	9.4877	Accept null

Table 5: Ramsey RESET specification test (null hypothesis: model correctly specified)

	F statistic	Critical F at 5% level	Decision
RESET(2)	0.5378	4.45	Accept null
RESET(3)	0.3446	4.49	Accept null
RESET(4)	0.2232	4.54	Accept null

Figure 1: Countrywide time series of rice output and inputs, 1977-1998

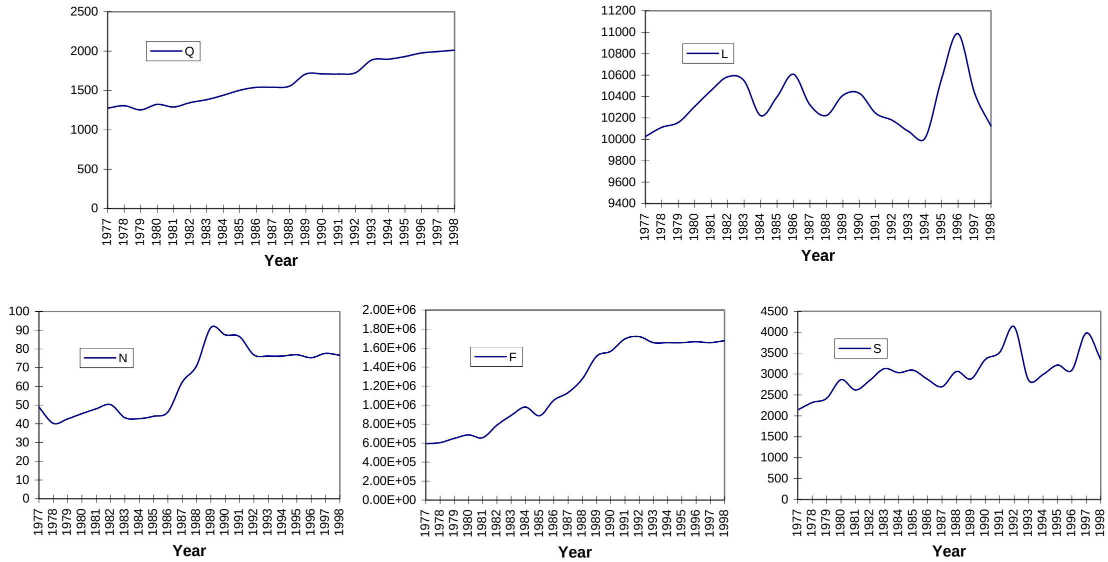

Figure 2: Rice output price and input price index, 1979-1998 (base 1983)

Figure 3: Index for TFP (A) and the incentive component of TFP (Ainc), 1979-1998 (base 1983)

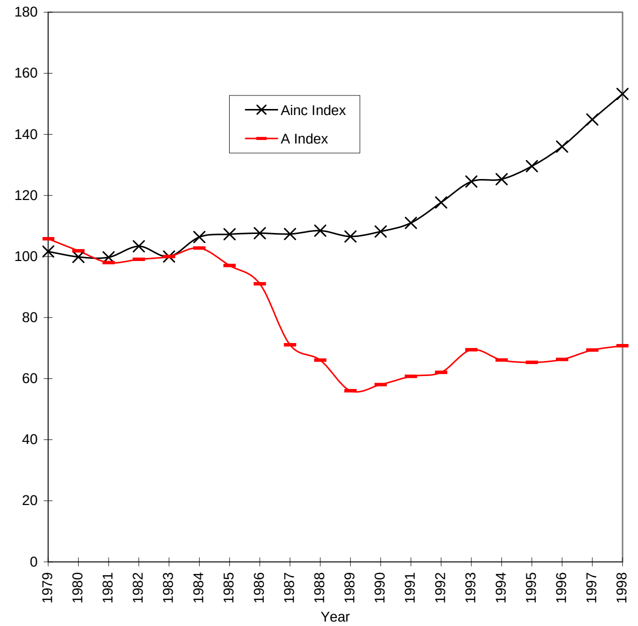

Figure 4: Growth in TFP (A) and the incentive component of TFP (Ainc), 1980-1998