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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 farmers' response to incentives due to major policy reforms during 1980s and 1990s.

Keywords: **Bangladesh, Incentives, TFP.**

JEL codes: **C33, C51, O13, Q12.**

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1. Introduction.

We measure the Total Factor Productivity (TFP) growth in rice production in Bangladesh and the incentive component of this growth. We compute the path of TFP growth and incentive component of TFP growth over three major policy regimes, namely, the input subsidy regime, the output price support regime, and the liberalized regime. We examine the incentive induced growth in TFP where the incentive to produce more is a result of policy reforms, captured by farmers' optimal response. We attempt to answer an important question: How do farmers respond to incentives?

We find that farmers, in general, respond to incentives, and deregulated markets induce farmers to exert more effort in search of higher productivity. Our study clearly shows that a major source of productivity growth in agriculture is incentive effects.

2. The Context.

In Bangladesh, during the early eighties a number of reform measures were taken to boost up domestic agricultural production and enhance factor productivity. This process was followed up by further reforms towards greater liberalized regimes. Privatization in factor supply chain and agricultural marketing were introduced and flat subsidies were replaced by effective incentive devices in order to promote domestic agricultural markets. These key reforms possess a history, and we consult various *Five-Year Plan* Documents of the *Ministry of Finance and Planning* of the Government of Bangladesh in order to present a summary of the history here.

Until 1980, farmers received input subsidy (but no wage subsidy) while the final market had a strict measure of quantity rationing. This phase of very low agricultural growth, attributable also to low level of technology, can be characterized as one of traditional agriculture with overwhelming dependence on weather. This encouraged the government to adopt a new input technology package. In addition, until late eighties, the government undertook output price support policy which included withdrawal of food subsidies in the urban rationing system and withdrawal of agricultural input subsidies. One of the main reasons behind the output price support policy was that the rate of increase in prices of imported fertilizer and improved seeds was persistently higher than the rate of increase in rice price. This difference was mainly due to noisy distributional channels for inputs. It was recognized that given the weak distributional channels of inputs, when prices fluctuate with output only price support policy to stimulate output is often ineffective. In order to improve the distributional channels, the government decided to move towards deregulation. Starting from 1990, the agricultural reforms can be characterized as ones of regulatory reforms of input supply side towards deregulation and liberalization of input supply chains, crop diversification, and extended rice research and widening genetic base of rice. Instead of mono rice cropping, multi rice cropping and round the year rice cropping were introduced. Major policies taken in this period included privatization of fertilizer and improved seeds supply, management and distributional reforms of fertilizer and irrigation equipment, and changing the output price policy to reflect *incentive* prices rather than procurement prices. Private traders were allowed to import diesel engines without taxes or restrictions, couple these engines with domestic pumps and pipes, and sell the equipment to farmers. The government removed all import duties and standardization restrictions of power tillers, and eliminated many restrictions on pesticide importation.

In this paper we use a simple model to capture farmers' optimal response to policy reforms, where reforms generate incentive to produce more. We follow the approach as in Hayami and Ruttan (1985), which McMillan, Whalley and Zhu (1989) and Zhang and Carter (1997) use to study agricultural productivity growth in China, and Chen, Kompas and Vousden (1999) use to study Vietnamese agriculture. Assuming that in transitional economies factor and product prices generally increase at different rates with market reform, we characterize this process through a weighted-cost share parameter which measures the ratio of average factor to product prices under various policy regimes. As is true for most transitional economies, the value of this share-cost parameter falls with reform. Changes in factor prices lag behind the increases in product prices and the result implies that average per unit profits rise over time. We use this line of argument and transform a technical production function into an institutional production function that reflects farmers optimal response to institutional and policy settings. We estimate it using rice production data for Bangladesh, and use the estimates to simulate TFP and its incentive component.

3. The Model.

The level of effort of a farmer is denoted by e, so that for N workers eN is the effective contribution of labour to output measured in *efficiency* units[2]. We assume the *technical* constant returns to scale (CRTS) production function takes the form

$$Q_r = a_0 (eN)^{a_1} (L)^{a_2} (S)^{a_3} (F)^{a_4} \qquad (1)$$

Where Q_r, L, F, S represent output of rice, land area under cultivation of rice, fertilizers and improved seeds used in producing rice. In per capita terms:

$$q_r = a_0 e^{a_1} l^{a_2} s^{a_3} f^{a_4} \qquad (2)$$

We define farm income:

$$m = pq \qquad (3)$$

where p is the market price of rice. Farmer chooses inputs in order to minimize costs. With CRTS assumption, the total cost function (TC) is given by:

$$TC = x \prod_i w_i^{a_i} Q_r \qquad (4)$$

[2] We define effort broadly that includes everything that determines the quality of the farmer's labour as well as the willingness to literally exert more effort due to the enhanced incentives that accompany economic reform and the removal of externally imposed restrictions on the kinds of tasks a farmer may undertake.

where $x > 0$ is a constant, and w_i are the input prices indexed across labour, land, fertilizer and improved seeds. With the average real factor price $\Gamma(w) = \prod_i w_i^{a_i}$, the cost of production per farmer is given by:

$$C = x\,\Gamma(w)q \qquad (5)$$

We define $w \equiv p^{-1}\Gamma(w)$ as the ratio of observed average factor to product prices. With (3), the farmer's profit function becomes,

$$p = p[q(1-xw)] \qquad (6)$$

Farmers like income but dislike the effort of hard work, and their utility function is:

$$u(p, e) = p - \frac{e^q}{qj}; \qquad j > 0, q > 1 \qquad (7)$$

The effort-disutility coefficient q is analogous to the coefficient of risk aversion and j is chosen to guarantee that the utility function jointly quasiconcave. Substituting from (2) and (6) gives

$$u(p, e) = p[a_0 e^{a_1} l^{a_2} s^{a_3} f^{a_4}(1-xw)] - \frac{e^q}{qj} \qquad (8)$$

The farmer chooses effort level to maximize (8). The optimal values for effort level satisfy:

$$(e^*)^n = \left[j\ \ p(1-xw)a_0 a_1 l^{a_2} s^{a_3} f^{a_4}\right] \qquad (9)$$

for $n = (q - a_1)$. Equations (9) and (2) together imply that the *institutional* production function is:

$$Q_r = [a_0^{n^{-1}q}\{a_1 p j(1-xw)\}^{n^{-1}a_1}] N^{g_1} L^{g_2} S^{g_3} F^{g_4} \qquad (10)$$

where $g_1 = (n)^{-1}(qa_1 - a_1), g_2 = (n)^{-1}qa_2, g_3 = (n)^{-1}qa_3, g_4 = (n)^{-1}qa_4$ for labour, land, seeds and fertilizers respectively. We define $A \equiv a_0^{n^{-1}q}\{a_1 p j(1-xw)\}^{n^{-1}a_1}$ as the total factor productivity (TFP) coefficient. The institutional production function is assumed to capture the farmer's response to institutional arrangements and government policies, through changes in prices p and the average ratio of input to product prices w. With observable data, it is the institutional production function that would be estimated rather than the technical production function defined by (1). We use the estimates from the institutional production function to decompose TFP into two components; the first attributable to incentive effects as captured in the effort variables, or

$$A_{incentive} = [p(1 - xw)]^{n^{-1} a_1} \quad (11)$$

and the other

$$A_{other} = [j^{a_1} a_1^{a_1} a_0^{q}]^{n^{-1}} \quad (12)$$

which is an unexplained residual reflecting the influence of a host of other factors.

4. Data and Estimation.

We use cross sectional data of 23 major rice producing districts in a given year (1997) in order to estimate the institutional rice production function. These data are collected from *Yearbook of Agricultural Statistics of Bangladesh*, a publication of Bangladesh Bureau of Statistics (BBS)[3]. The selected districts have similar cropping intensity. We also collect time series data on country-wide aggregate production, input use and price from the same source. We present a data appendix that explains the variables we use and presents the summary statistics. Figure 1 and figure 2a in appendix presents the time series data.

The results from Ordinary Least Squares (OLS) estimation of the institutional production function are presented in appendix where the share coefficients of labour, land, seeds and fertilizer are 0.22, 0.45, 0.17 and 0.15, respectively. These are statistically significant at 5% level. Note that since $n = (g_1)^{-1}(qa_1 - a_1) = (g_2)^{-1} qa_2$, the value of the work-disutility coefficient is equal to 3.01339. The computed values of a_is are 0.3, 0.41, 0.15 and 0.14 for inputs labour, land, seeds and fertilizer, respectively. With time series data on input prices, one can compute $x = 0.037$. We perform a number of diagnostic tests and their summary are in appendix. All tests of heteroscedasticity produced low values of the test statistic, and therefore we accept the null hypothesis of homoscedasticity in the distribution of residuals. We conduct the Ramsey's standard tests of specification error, called the RESET (regression specification error test). The F statistics calculated in the RESET are based on R^2 values of the auxiliary and unrestricted regression models. All tests of Ramsey's RESET indicate that the hypothesis of misspecification of the model could not be accepted at 5% level of significance. We test the normality of the distribution of residuals using the standard Jarque-Bera (JB) test. We accept the normality assumption of the distribution of the OLS residuals at 1% level.

5. Total Factor Productivity with Economic Reform.

We use time series data on rice output and inputs for Bangladesh and compute total factor productivity (TFP) growth, as Solow residual for each of the years 1979-1998. The annual growth rate for total factor productivity (A) is calculated in the usual growth accounting manner as the difference between the growth of output and the growth of each input weighted by share parameters. The resulting estimates of the year-by-year growth rates for A are then used to calculate an index for TFP.

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

We present the TFP index and its density and distribution in figure 2a and 2b in appendix. We present the TFP growth time path in figure 3. The results are striking. Prior to the output price support period of 1982-1989, under highly regulated market for inputs where inputs were subsidized, TFP growth rate was negative. During this period, with heavily subsidized inputs structure, there was no incentive for farmers to enhance 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 1% in 1982. However, there was positive growth in TFP only until 1985. It reached a record minimum of – 1.5% in 1986, improved thereafter but remained negative until 1990. The output price support policy failed to sustain the favourable impacts of factor productivity due to its mismanagement and lack of institutional reforms towards improving factor market competition. Reform towards liberalization in the market for inputs brought in remarkable success in the early nineties. TFP growth rate reached a new peak of 2% in 1992, and continued to be nonnegative until 1995.

We compute the time path of the incentive component of TFP, $A_{incentives}$, using the time series data on input costs and output price of rice. The growth in this component is presented in figure 3. There is clear evidence of incentive induced growth in TFP during the output price support policy regime (peak 6.3%) and current liberalized input markets regime (peak 6%). The fall in growth of incentive component in 1988 may be attributable to heavy flood which resulted in huge crop damage. Its recovery in 1989 is perhaps due to bumper harvest. The overall trend of the incentive component of TFP growth during the reform periods (1982-1998) is quite interesting, revealing that farmers respond to policy changes that induce more incentives for enhancing factor productivity.

When most inputs were subsidized and quantity was rationed (until 1980), farmers had no incentives to increase factor productivity in anticipation of competition in factor as well as product market in future. The growth rate of TFP and its incentive component experienced a boost with the introduction of output price support policy. In this phase of reform, due to the removal of direct input subsidies, agricultural factor markets became more competitive and all input prices had a growth rate which was higher than the output price growth rate. This growth was followed by a high growth of incentive-induced productivity. The beginning of nineties was characterized by a shift from more regulated policy regimes towards further liberalization in input supply side. Flat subsidies and supports were removed and replaced by more effective incentive devices such as fiscal waivers on licensing, privatization of fertilizer and seeds supply, institutional reforms such as introducing transferability of supply licenses (at market determined rate), improved and strategic land management schemes and increased volume of agricultural research. This corresponds to our finding that there was positive growth in incentive component of TFP during the nineties. Our results indicate that no matter how informal the agricultural labour market is, farmers respond sensibly to policy changes and market reforms that are directed towards generating more incentives for enhanced factor productivity. There is, obviously, a large component of TFP growth which we do not explain. This component can be accounted for unexplained factors such as weather variations or land fertility.

6. Concluding Remarks.

We use a simple optimizing model, and our empirical study is based on an institutional production function which reflects not only the usual technical relationship between inputs and outputs, but also effort responses to the institutional and market arrangements within which farmers work. Assuming farmers choose their effort levels optimally, it is possible to estimate these incentive effects at each stage of reform 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 towards incentives in policy reform. Our results clearly show that the incentive component of TFP in rice production in Bangladesh has experienced steady increase during the most recent policy reform towards liberalization and deregulation of markets.

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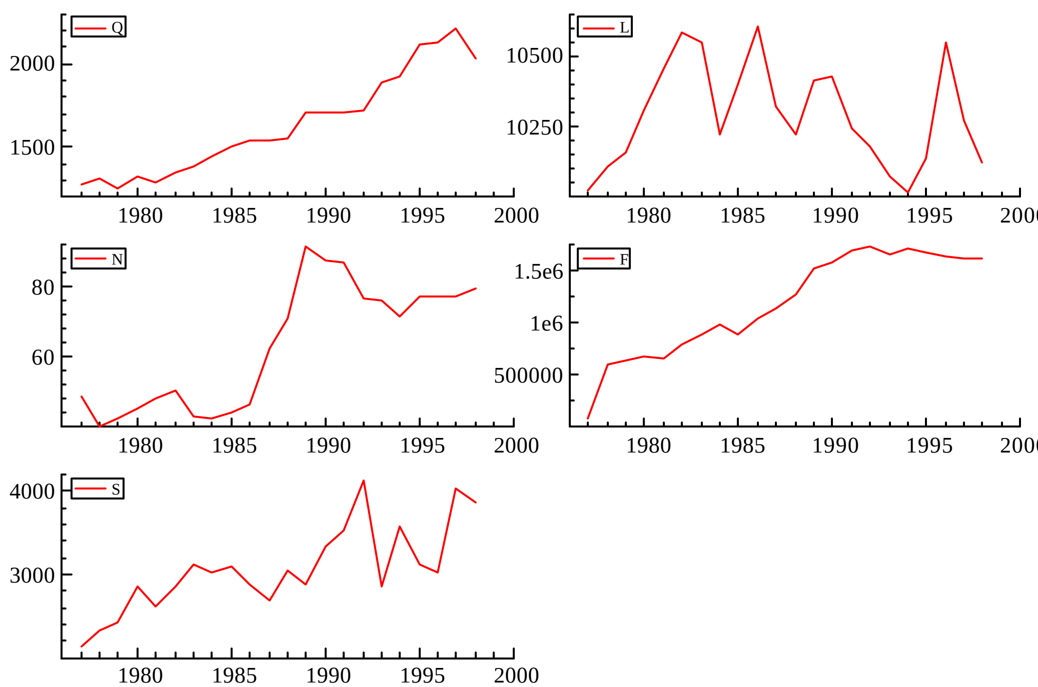
Data Appendix.

The output data for rice is an aggregate rice production data; 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 aggregate district/national production of rice in tonnes for cross sectional/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. The land input is measured as the sown area of rice. The proportion of land that is used for rice production was measured deflating land area in hectares under cultivation of rice by total land area in hectares available for cropping throughout the year. This fraction for different districts, and as well for the country-wide level was used to transform other input variables for per hectare input usage. The seed input is calculated from the average use of hybrid seeds and it is measured in tonnes multiplied by proportion of land under rice cultivation. In this way we get how much seeds are used per hectare in rice production. The chemical fertilizer is calculated from the average amounts of major hybrids of chemical fertilizer, namely, Urea, TSP, SSP and ASP, used per hectare in rice production. Time series data for rice prices for 1979-1998 was obtained from the survey of Bangladesh Rice Research Institute in different years and the database of SDNBD. All rice prices are average annual wholesale price of popular hybrids, valued in Taka (Bangladeshi currency) per mound (a rural unit of measurement of rice, where 1 mound = 40 Kg). Time series data on input prices for the period 1979-1998, used to construct the weighted-cost share parameter *w*, are collected mainly from Agricultural Statistical Yearbook of Bangladesh of BBS, and database of SDNBD. Chemical fertilizers and seeds prices are measured in Taka per kg labour price. Wage rates are aggregate average wage rates for male and female workers without meal. The land input price or land rental is measured by the amount of money farmers have to give to the land owner in local currency for each mound produced in 1 hectare of land during a cropping season. To get land rental paid per kg rice produced in 1 hectare of land, rental rates were divided by 40.

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	Land area in district i (in 000 hectares) under cultivation.	*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)*	*2,643.16*	*1,12,211*
Labour	Labour in district i (in 000 work days).	*3.48 (0.775)*	*1.802*	*6.15*

Figure 1: Country-wide time series of inputs and rice output (1977-1998).



Q, F and S are rice output, chemical fertilizers and improved seeds, in thousand tonnes, L is land area under cultivation of rice, in thousand hectares, and N is labour work days in thousand.

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

Variable Name	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-Square	*0.9711*	
R-Square Adjusted	*0.9626*	
Standard error of estimation	*0.2203*	

Table 3: Summary of likelihood ratio test for CRTS and Jarque-Bera test for testing normality of distribution of residuals.

Null hypothesis	Test Statistic	Critical Value	Decision
$g_1 + g_2 + g_3 + g_4 = 1(CRTS)$	*4.69*	*6.6349*	*Accept Null*
Normal distribution of OLS residuals	*7.7649*	*9.21*	*Accept Null*

Table 4: Heteroscedasticity tests
Null hypothesis: Homoscedasticity

($u \equiv$ residual $\hat{q} \equiv$ predicted)	χ^2 statistic	Critical χ^2 At 5% level	Decision
u^2 on $\hat{q}$	*0.221*	*3.8414*	*Accept Null*
u^2 on $\hat{q}$	*0.199*	*3.8414*	*Accept Null*
u^2 on $\ln \hat{q}$	*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)	*0.53783*	*4.45*	*Accept Null*
RESET (3)	*0.34460*	*4.49*	*Accept Null*
RESET (4)	*0.22324*	*4.54*	*Accept Null*

Figure 2a: Price, profit per unit, TFP index and incentive component of TFP index (1977-1998).

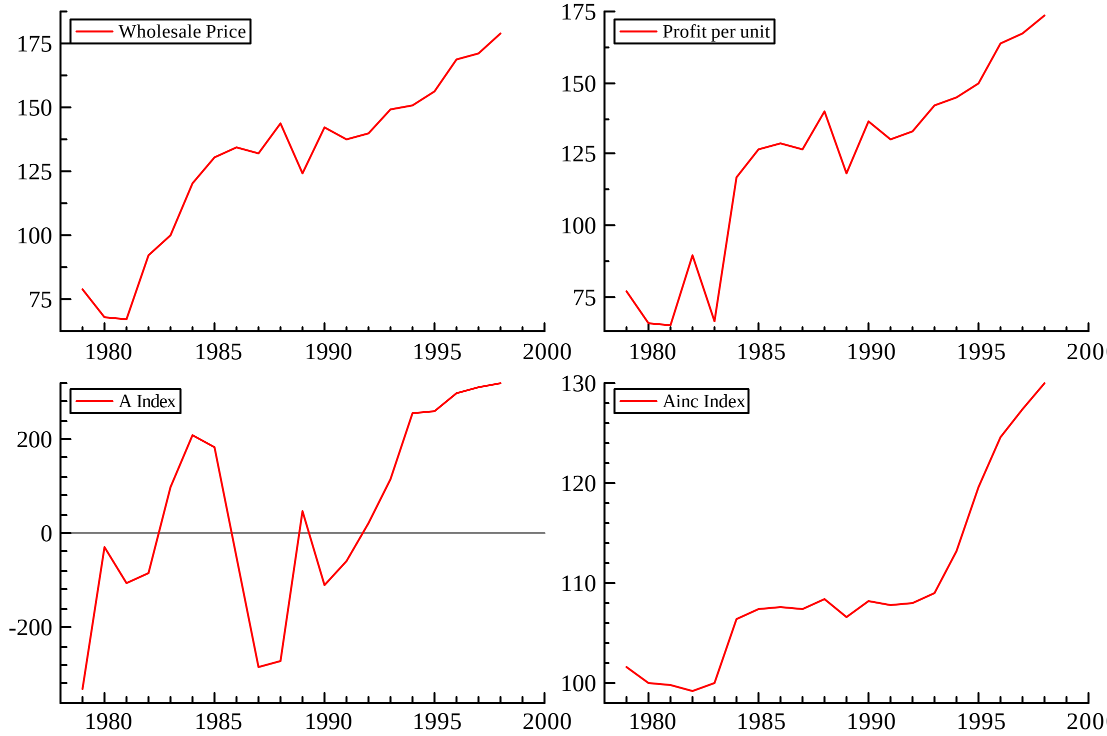


Figure 2b: Density and distribution (against normal) of TFP (A) and Incentive Component of TFP (Ainc) Index (1977-1998).

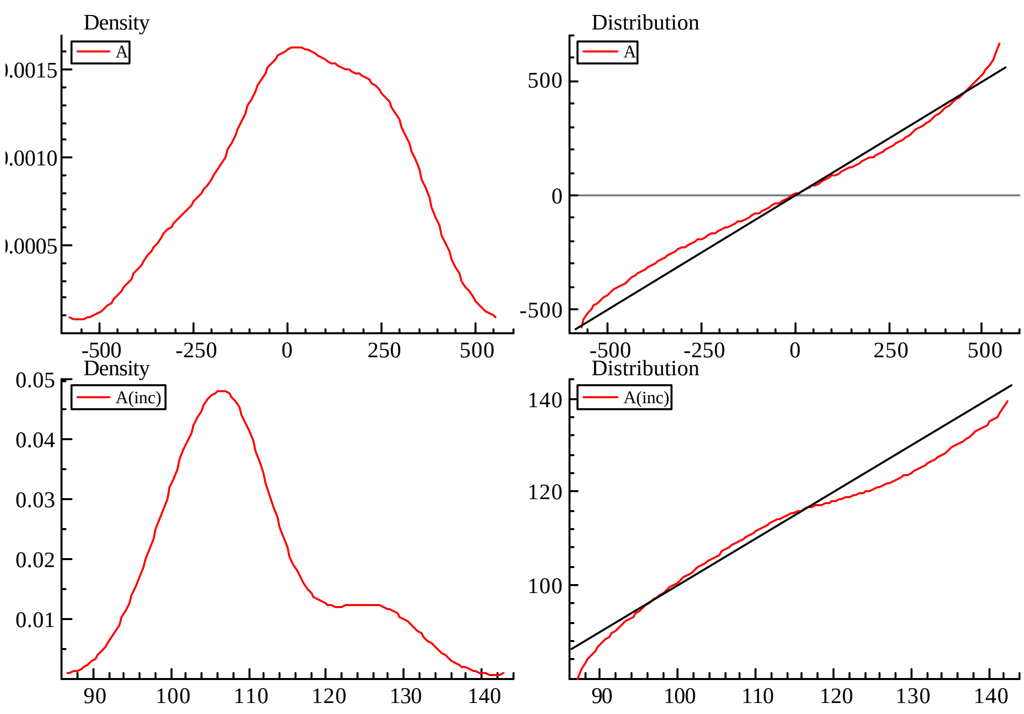


Figure 3: Growth in TFP and Incentive Component of TFP (1977-1998).