Total Factor Productivity Growth in Indian Agriculture

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1. Introduction

During the post-Green revolution period, rising output per hectare replaced expansion of cropland as the predominant source of agricultural growth in India (Tripathi and Prasad 2008). The transition from agricultural extensification to intensification was probably most noticeable in Asia, where population density is relatively high and land scarcity most acute. In this paper, we examine the performance of agricultural productivity in India during the last 37 years. Although agriculture's share of the economy of India declined over this period, agriculture still provided the main livelihood for 60 percent of the nation's population. Sustaining productivity growth in agriculture continues to be critical for achieving food security, poverty reduction, and broad-based economic growth.

In this study, we use time series data related to broad agricultural outputs which included farming, livestock, forestry, and fisheries and 3 conventional inputs: labour, land, and capital, to construct an index of total factor productivity (TFP) between 1969-70 to 2005-06. A TFP index is simply the ratio of an output index to an input index. Therefore, growth in TFP is the residual share of output growth after accounting for changes in land, labor, and other conventional agricultural inputs. Changes in TFP can be interpreted as a measure of the collective contribution of non-conventional inputs in agriculture, such as improvements in input quality, market access, economies of scale, and technology (Alston, Norton and Pardey, 1995).

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What emerges from this exercise is a picture that raises concern about future growth in Indian agriculture, and the welfare of the people who depend on agriculture for their livelihood. Agricultural productivity in India appeared to stagnate in the late 1990s after enjoying two decades of rapid growth. We conjecture that without major increases in public and private investments in Indian agriculture, it will not return to a path of sustained productivity growth.

2. Methodology

a. Model and Estimation Procedure

Productivity can be defined as a ratio of the output to inputs used in production. An increase in the amount of output per unit of input, equivalent to an outward shift in a production function, is then measured as an increase in factor productivity. Partial productivity indices, such as output per worker, give the ratio of output to a single factor of production. However, since the amounts of other inputs may vary, increases in output per worker can result from either increase in the use of other inputs or to changes in technology. An index of total factor productivity (TFP) compares changes in output with changes in aggregate inputs. Changes in TFP provide a better picture of changes in technology and other unmeasured improvements in the means of production (such as improvements in input quality). In applications of TFP measurements to agriculture, it is common to aggregate crop and animal outputs and conventional inputs (land, labor, and capital services) using market or shadow prices as weights (Alston, Norton and Pardey, 1995).

In this study, arithmetic index is used to measure TFP for the agriculture sector. It is defined as a ratio of the total output index to input index, with the input index constructed as a linear of inputs with production function approach. Following Wen (1993), the simplest version of a TFP index can be algebraically written as: The index can be easily derived assuming a linear homogenous production function and competitive labour markets. Despite its theoretical limitation, it is the easiest to calculate.

$$TFPI = {100 \times GVAO} \Big/ {\alpha \times labour + \beta \times land + \gamma \times capital} \qquad \cdots (1)$$

Where, output index in the numerator is based on the Gross Value of Agricultural Output(GVAO) and input index in the denominator is a linear aggregation of net sown area (land), agricultural labour, and capital, using α, β, and γ (production elasticities with respect to labour, land, and capital) as weights.

There are two approaches for input aggregation; one is index number and other is production function approach. In this study, we use production function approach for aggregating inputs.

For production function approach, we estimate Cobb-Douglas production function with constant returns to scale (CRS). Under CRS and profit maximization, the production elasticities equal factor shares and sum to one (Peterson, 1999). While this imposes a fixed set of factor shares over the period, it does provide another means of deriving weights for input categories for which accurate time series of factor prices are unavailable.

With three conventional inputs, the Cobb-Douglas production function can be written as

$$Y = AL^{\alpha}M^{\beta}K^{\gamma}$$
…(2)

where *Y* is gross value of agricultural output; *L* is agricultural labor force; *K* is capital input; *M* is agricultural land; The coefficients *α, β, and γ* are the elasticities of the respective variables with respect to agricultural production, with the assumption that $\alpha + \beta + \gamma = 1$. Eq. (2) of production function in log form is:

$$\ln Y = \beta_0 + \alpha \ln L + \beta \ln M + \gamma \ln K$$
…(3)

Further, imposing restriction of CRS, the Cobb-Douglas production function can be rewritten as

$$\ln Y/L = \beta_0 + \beta \ln M/L + \gamma \ln K/L$$
…(4)

Estimation of agricultural production functions from aggregate time series data is plagued by a number of problems. First, explanatory variables are often highly correlated. Using OLS with multicollinear variables may provide unreliable results. Second, using national annual data limits the degrees of freedom available, and therefore reduces the effective number of variables that can be included in the model. Third, there are often considerable uncertainties about the quality and accuracy of the data, particularly of agricultural land and labor inputs. Fourth, specific function forms necessarily impose a certain structure on the production process – the Cobb-Douglas function, for example, assumes unitary elasticity of substitution between any two inputs. Finally, estimation may suffer from endogeniety of the X variables, since the quantity of inputs to allocate to agricultural production is also part of farmers' decisions.

In light of these considerations, our approach to production function estimation in this study is to estimate a restricted model with few variables so that the resulting estimates are robust. We impose constant returns to scale on the Cobb-Douglas production function and aggregate conventional inputs into three categories (land, labor, and capital stock). Restricting the model's structure and number of variables reduces the multicollinearity problem associated with OLS. Other approaches to dealing with multicollinearity, such as ridge regression or principal components analysis, have their own drawbacks. Ridge regression introduces an arbitrary numerical adjustment to the data. The principal component estimator is a mixture of the original coefficients in the model and may be difficult to interpret. Both the ridge regression and principal component estimators are also biased (Greene, 1993).

b. Period of the Study

The period from 1969-70 to 2005-06 is selected in this study because Indian agriculture has shown remarkable growth after introduction of Green Revolution technologies in the late 1960s.

c.Data Source

The data used in this study were country level agricultural output and inputs for estimating the Cobb-Douglas production function of Indian agriculture from 1969-70 to 2005-06. Most previous studies on Indian agriculture used gross value of agricultural output (GVAO) as the total value of agricultural production. GVAO is defined as the sum of the total value of production from farming, forestry, livestock, and fishery. The sum of output of all products of farming, livestock, forestry, and fishery equals to GVAO and is expressed at 1999-2000 prices. The data on GVAO were taken from the National Account Statistics (NAS) published from Central Statistical Organization, Government of India

Labour, land, and capital are considered the three main inputs in agricultural production. Labur input is measured as workforce involved in agriculture. The data of workforce in agriculture is given in Agricultural Statistics at a Glance (2008) published from Directorate of Economics and Statistics, Ministry of Agriculture, Government of India only for census year. This series was interpolated for making time series data.

Land input refers to the net cultivated area and is measured by net sown area. The data were taken from Agricultural Statistics at a Glance.

Capital stock of a country is broadly referred to as that part of national wealth which is reproducible; it consists of all resources which contribute to the production of goods and services. Capital is measured in terms of net fixed capital stock in agriculture and data related to net fixed capital stock taken from Nation Account Statistics.

3. Results & Discussion

a. Agricultural Output Growth

In assessing overall growth of the Indian agriculture sector since 1969, we divided entire period into three sub periods. This division of periods is based on changing economic policies because economic policies positively affected to the farmers production decision. First period is 1969-70 to 1979-80, during this period, government started to create favorable environment for adopting new technology through increasing public investment, and by policy changes. Second period is 1980-81 to 1990-91, during this period, public investment started declining. Third period is 1991-92 to 2005-06, since 1991, the country initiated economic reforms for stabilizing economy. Further, the third period is again divided into two sub-periods: first is 1991-92 to 1995-96 and second is 1996-97 to 2005-06 to asses the impact of WTO on agriculture growth.

India produces a diverse set of agricultural commodities. Food crop is dominated by rice and wheat but also included several secondary food crops, especially Jawar, Bajara, Maize, and pulses. Production of non-food crops includes Sugar, Cotton, Oilseeds, Jute, Tea, Coffee, fruits and vegetables, and numerous types of spices. Milk products and poultry have been fastest growing components of animal production. Besides products of farming and livestock, fisheries and forestry are also important components of Indian agricultural sector. Table 1 and 2 shows the changing level and composition of agricultural output in India since 1969-70. Each columns report average output levels during each periods in real terms. Between 1970s and 1996-06, Gross value of agricultural output increased from 264622 Rs. Crores to 562792 Rs. Crores. Crop output was by far most important segment, accounting for about 72 percent of total agricultural output in 1970s and nearly 68 percent of total agricultural output in post WTO period. Value of crop output doubled during this period. For same period, value of livestock and fisheries were also increased more than two times. But according to the figures, value of forest product hardly grew during this period.

Table 1: Level and composition of agricultural output in India

Period	Crop	Livestock	Forestry	Fisheries	Aggregate
1969-70 to 2005-06	279064.8	87855.38	19018.14	14263.51	400201.83
1969-70 to 1979-80	190651.1	46811.82	19819.45	7339.364	264621.73
1980-81 to 1990-91	258510.8	76166.27	17512.18	10794.36	362983.61
1991-92 to 2005-06	358974.5	126526	19534.87	21885.27	526920.64
1991-92 to 1995-96	314381.6	105233.8	18028.6	17533.6	455177.6
1996-97 to 2005-06	381270.9	137172.1	20288	24061.1	562792.1

Note: Figures are given in Rs. Crore

Source: National Account Statistics (Back Series 1951-2000, & 2007)

Table 2: Level and composition of crop output in India

Name of all	1969-70 to	1969-70 to	1980-81 to	1991-92 to	1991-92 to	1996-97 to
Categories of Crops	2005-06	1979-80	1990-91	2005-06	1995-96	2005-06
Cereals	97677.78	67556.73	93014	123186.7	114696.8	127431.6
Corse Cereals	17127.92	15876.18	17206.82	17988	17482.4	18240.8
Pulses	16387.35	14388.64	16415.18	17832.67	17159.4	18169.3
Oilseeds	22362.14	13781.82	19484	30765	29554.8	31370.1
Sugar	13798.11	8926.273	11422.82	19112.67	14821.8	2128.1
Fibers	10586.92	7440.182	9384.818	13776.07	12861.2	14233.5
Drugs & Narcotics	6694.865	4512.455	5980.364	8819.267	7206.6	9625.6
Fruits & Vegetables	56576.35	33955.18	48156.64	79339.67	60678.6	88670.2
Condiments & Spices	10275.38	5595.455	8489.727	15016.8	11503.2	16773.6
Others	44705.92	34494.36	46163.27	51125.67	45899.2	53738.9

Note : Figures are given in Rs. Crore

Source: National Account Statistics (Back Series 1951-2000, & 2007)

Within crop sector, value of all categories of crops increased between 1970s and post WTO period. Among foodgrain crops, only cereals grew rapidly during this period. It was 67556.73 crores Rs. in 1970s and increased to 127431.6 crores Rs. in post WTO period. While values of output of both coarse cereals and pulses hardly grew during this period. The value of all non-foodgrain crops increased firstly in this period.

Tables (3& 4) show the growth rate of agricultural economy by sector and different crop wise. The aggregate agricultural output increased annually at 2.01 percent during 1970s, at 2.86 percent during 1980s and 2.62 percent during reforms period. The growth rate of aggregate agricultural output turned up 3.29 percent during the initial years of reforms, which was 0.43-percentage point higher than the previous period. Disaggregating of agriculture into sub sectors shows that fisheries was the main sources of the acceleration in growth rate of agricultural output in the initial years of reforms. However, the situation of agriculture turned adverse during post WTO period and this covered all the sub sectors of agriculture. The growth rates in output of all crops decelerated from 2.93 percent to 1.57 percent. The livestock declined from 4.21 percent to 3.40 percent. The fisheries declined from 7.48 percent to 3.25 percent. Only, forestry witnessed a sharp increase from 0.09 percent to 1.82 percent.

Table 3: Average Annual Growth Rates of Crops, Livestock, Forestry, Fisheries and Aggregate Output

Period	Crop	Livestock	Forestry	Fisheries	Aggregate
1969-70 to 2005-06	2.57	4.06	0.1	4.53	2.82
1969-70 to1979-80	1.79	3.56	-0.13	3.03	2.01
1980-81 to 1990-91	2.43	4.65	-0.006	5.58	2.86
1991-92 to 2005-06	2.28	3.49	1.58	4.06	2.62
1991-92 to 1995-96	2.93	4.21	0.09	7.48	3.29
1996-97 to 2005-06	1.57	3.40	1.82	3.25	2.10

Note: Annual compound growth rates have calculated by using of linear log model
Source: National Account Statistics (Back Series 1951-2000, & 2007)

Table 4: Average Annual Growth Rate of All Categories of Crops for Period of 1969-70 to 2005-06

Name of all Categories of Crops	1969-70 to 2005-06	1969-70 to1979-80	1980-81 to 1990-91	1991-92 to 2005-06	1991-92 to 1995-96	1996-97 to 2005-06
Cereals	2.4	2.34	3.03	1.05	2.16	.12
Corse Cereals	.52	.98	.70	.53	.37	.39
Pulses	.85	-.32	1.91	.43	1.05	-.32
Oilseeds	3.16	.40	5.47	.76	3.89	.57

Sugar	3.17	1.54	2.62	4.18	2.72	3.25
Fibers	2.5	2.38	2.67	1.62	5.77	2.28
Drugs & Narcotics	2.81	3.85	2.41	2.69	1.58	.20
Fruits & Vegetables	3.52	3.27	2.3	4.3	5.5	2.43
Condiments & Spices	4.15	3.29	4.43	4.95	4.59	5.06
Others	1.52	.10	-.29	2.33	.62	3.19

Note: Annual compound growth rates have calculated by using of linear log model
Source: National Account Statistics (Back Series 1951-2000, & 2007)

The crop sector, which forms largest segment of agriculture, showed poorest growth during post WTO period in comparison to all other periods. Further, within crop sector, all crops except sugar showed declining trend between initial years of reforms and post WTO period. This deceleration is very high in Cereals, Corse Cereals, Pulses, Oilseeds, and Drugs & Narcotics. The growth rate turned negative in the case of pulses.

These growth rates are lower than the growth rate of rural population. Thus, it is clear implication of this growth trends is that the per capita output in agriculture is declining. This seems to be one of the causes for rising disparity between rural and urban area in India.

b. Agricultural Input Use

Table 5 provides a breakdown average annual growth rates of inputs used in Indian Agriculture over the entire period and during the five sub periods described above. Net sown area continued to expand at about 0.02 percent per year through out the entire period. The growth rate of Net sown area was 0.14 percent for 1970s but this is decreased to -0.35 percent per year in post WTO period. Irrigated crop land expanded 2.3 percent per year during 1969-70 to 2005-06, slightly more than the overall growth in the crop land. The agricultural labour force also grew continuously over the entire period, and was still growing at about 3.17 percent in the post WTO period. Capital grew by an average of 2.83 percent per year during 1969-70 to 2005-06. The growth in capital was low in initial period of reform during this period capital expanded by only 1.85 percent per year while it grew by 3.04 percent in post WTO period

Table 5: Annual compound growth rates of labour, land and capital used in Agriculture

Period	Labour	Land	Capital
1969-70 to 2004-05	2.2	0.02	2.83
1969-70 to1979-80	1.47	0.14	3.81
1980-81 to 1990-91	2.26	0.02	2.48
1991-92 to 2005-06	2.70	-0.21	2.58

1991-92 to 1995-96	2.08	0.10	1.85
1996-97 to 2005-06	3.17	-0.35	3.04

Note: Annual compound growth rates have calculated by using of linear log model.

Source: National Account Statistics (Back Series 1951-2000, & 2007)

c. Cobb-Douglas Estimates for Indian Agriculture

OLS estimates of a Cobb-Douglas production function for Indian agriculture are presented in Table 6. Constant returns to scale are imposed on the model to reduce the number of free parameters to estimate to three. With constant returns to scale, the estimated production elasticities are sum to one. All of the conventional inputs contributed significantly to labor productivity (at the 1% significance level). The production elasticity of land is -0.169, virtually less than others estimate. Craig, Pardey and Roseboom's (1997) estimate 0.35 of the production elasticity of land in developing countries and Fuglie (2002) estimate 0.346 in Indonesian agriculture. The production elasticity of labour is 0.82 which is high relative to estimate from other developing countries.). The production elasticity of capital is 0.349.

From a purely statistical viewpoint, the estimate regression line fits the data quite well. The R^2 value of 0.68 means that 68 percent of the variation in the (natural logarithmic of) gross value of agricultural output/ labour is explained by the (natural logarithmic of) land/ labour, and capital/ labour. For adjusted R^2 the relation is 66 percent . This shows the statistical dependence of the (natural logarithmic of) gross value of agricultural output/ labour on the (natural logarithmic of) land/ labour, and capital/ labour. β and γ are statistical significant at the 1 percent level. The dw statistics is equal to 1.591, it is greater than the value of d_u and less than $(4-d_u)$. It is inference that there is no autocorrelation.

Table 6: Results of Cobb-Doglas Production Function

Variables	Coeff.	Std. Err.	t- Value	R^2	Adj- R^2	DW-Stat.
Cons.	7.55	1.534128	4.92	0.68	0.66	1.59
Nsa/ labr	-0.17	0.0469813	-3.60			
Cptl/ labr	0.35	0.1267888	2.76			

Note: Dependent Variable is GVAO/ Labr

Table 7: Production Elasticites of Land, Labour, and Capital

Factors	Value of Production Elasticity
Land	-0.17

Labour	0.82
Capital	0.35

d. Agricultural Total Factor Productivity

With estimates of aggregate outputs and inputs, the index of total factor productivity (TFP) for Indian agriculture is found by simply taking the ratio of the output index to the input index. TFP index is presented in Table 8 and Figure 1. The production elasticities estimated from the Cobb-Douglas function were used in input aggregation.

The TFP index suggests that agricultural total factor productivity growth was negative during entire period and it is equal to 0.11 percent. TFP growth was also negative for period 1969-70 to 1979-80 and 1980-81 to 1990-91 and increased to 0.93 percent in initial years of reforms. But again agricultural TFP growth slowdown and decreased to -1.87 percent during post WTO period.

With these estimates it is possible to decompose total growth in output into a component due to increases in conventional factors of production and a component due to productivity improvement. Table 9 summarizes these results. During 1969-70 to 2005-06, the average annual agricultural growth in overall agriculture was 2.82 percent, of which 2.93 percent was due to increase in land, labour, and capital and -0.11 was due to improvements in agricultural TFP. Increases in agricultural TFP were evident from 1969 to 1996 and growth was positive only during initial years of reforms.

Table 8: Indices of Output, Input (Aggregate), and Total Factor Productivity (TFP)

Year	Output Index	Input Index	TFP Index
1969-70	42.835	43.2	99.2
1970-71	45.427	43.8	103.7
1971-72	45.190	44.8	100.9
1972-73	43.345	46.2	93.8
1973-74	46.125	46.8	98.7
1974-75	46.029	48.5	95.0
1975-76	50.930	49.4	103.1
1976-77	48.607	51.4	94.6
1977-78	52.869	52.8	100.1
1978-79	54.321	54.6	99.6
1979-80	49.213	57.1	86.1

1980-81	56.337	59.1	95.3
1981-82	58.722	60.8	96.6
1982-83	58.712	63.0	93.2
1983-84	63.655	64.8	98.3
1984-85	64.721	67.0	96.7
1985-86	65.054	68.8	94.5
1986-87	65.020	70.9	91.7
1987-88	63.928	73.6	86.8
1988-89	73.049	74.7	97.8
1989-90	74.031	76.6	96.7
1990-91	76.767	79.0	97.1
1991-92	75.754	81.0	93.5
1992-93	79.928	83.0	96.3
1993-94	82.558	85.1	97.1
1994-95	86.140	86.9	99.1
1995-96	86.014	89.1	96.6
1996-97	93.049	91.2	102.0
1997-98	91.746	93.7	97.9
1998-99	97.494	96.3	101.2
1999-00	100.000	100.0	100.0
2000-01	99.263	103.7	95.7
2001-02	105.282	107.9	97.6
2002-03	98.645	113.5	86.9
2003-04	107.629	117.3	91.7
2004-05	107.865	122.8	87.9

Figure (1)

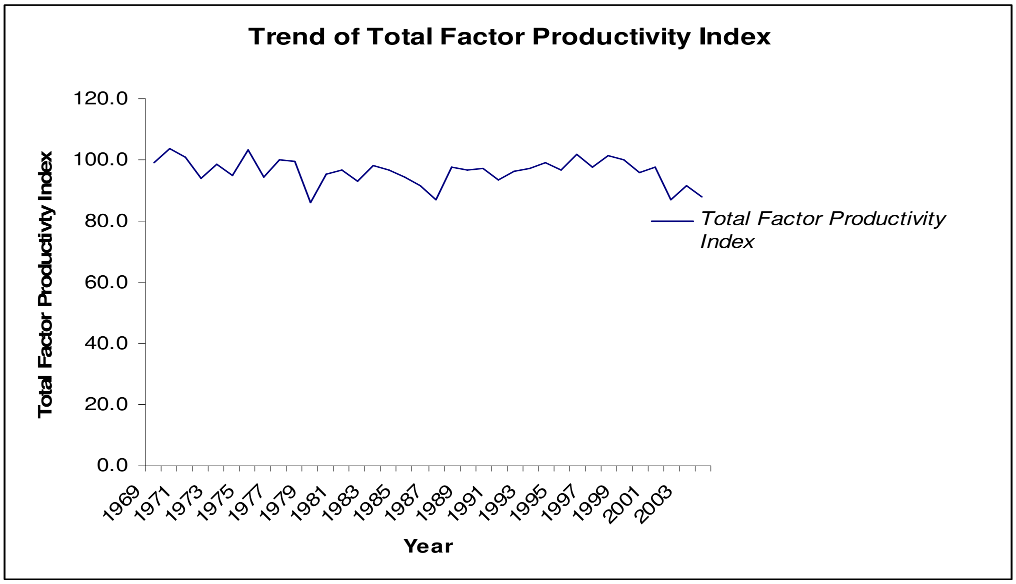

Table 9: Sources of Agricultural Growth

Period	Output Growth	Input Growth	TFP Growth
1969-70 to 2004-05	2.82	2.93	-0.11
1969-70 to1979-80	2.01	2.76	-0.76
1980-81 to 1990-91	2.86	2.91	-0.05
1991-92 to 2005-06	2.61	3.16	-0.55
1991-92 to 1995-96	3.29	2.37	0.94
1996-97 to 2005-06	1.91	3.78	-1.87

Thus, the growth in agricultural output is due to increases in land, labour, and capital in agriculture for entire period as well as all sub periods except period 1991-92 to 1995-96.

4. Conclusion

Our estimation showed that between 1969 and 2005, agricultural growth relied almost entirely on increased in conventional factors while growth in productivity was negative. For only initial periods of reforms, agricultural TFP growth is positive.

While a careful examination of the underlying causes of the productivity slowdown in Indian agriculture is beyond the scope of this study, we can suggest some probable causes. Probably a more important explanation for the productivity slowdown is a relative decline in public investments in the agricultural sector. The public investment in agriculture in India fell in the 1990s as a percentage of agricultural GDP (Raghabendra Jha 2007).

Approved (domestic and foreign) private investment in agriculture increased rapidly but unevenly until the macroeconomic crisis of 1997-1998 and has not yet recovered. The stagnation of TFP growth has serious implications for the long-term performance of Indian agriculture. As we move into the 21st Century, it will be increasingly difficult to expand convention factors of production such as agricultural land and labor, and without growth in TFP, agricultural output will continue to stagnate or grow only very slowly. This will further erode the profitability of agriculture and speed the drain of resources away from agriculture and rural areas to other sectors of the economy. It will undermine the important role of agricultural growth in reducing poverty and generating broad-based economic growth for the Indian economy.

Reference:

Alston, Julian M., George W. Norton and Philip G. Pardey. 1995. *Science Under Scarcity: Principles and Practice for Agricultural Research Evaluation and Priority Setting*. Ithaca, NY: Cornell University Press.

Craig, Barbara J., Philip G. Pardey, and Johannes Roseboom. (1997). "International Productivity Patterns: Accounting for Input Quality, Infrastructure, and Research". *American Journal of Agricultural Economics* 79 (November): 1064-1076.

Fan, Shenggen and Xiaobo Zhang. (2002), "Production and Productivity Growth in Chinese Agriculture: New National and Regional Measures". *Economic Development and Cultural Change*.

Fan, Shenggen, Peter Hazell, and Sukhadeo Thorat. (1999), "Linkages Between Government Spending, Growth, and Poverty in Rural India". Research Report 110. International Food Policy Research Institute, Washington, DC.

Fuglie, K. O. (2004), "Productivity Growth in Indonesian Agriculture". *Bulletin of Indonesian Economic Studies* 40 (2): 209-225

Fuglie, Keith O. (1999), "Investing in Agricultural Productivity in Indonesia". *Forum Penelitian Agro Ekonomi* 17,2 (December): 1-16.

Government of India (2008), Agricultural Statistics at a Glance. Directorate of Economics and Statistics, Ministry of Agriculture, New Delhi.

Government of India (2008), National Account statistics (Back Series). Central Statistical Organization, Ministry of statistics and Programme Implementation, New Delhi.

Government of India (2008), National Account statistics. Central Statistical Organization, Ministry of statistics and Programme Implementation, New Delhi.

Greene, William H. (1993), *Econometric Analysis, 2nd edition*. Prentice Hall, Englewood Cliffs, NJ.

Jha, R (2007), "Investment and Subsidies in Indian Agriculture". ASARC Working Paper 2007/03.

Peterson, Willis. (2000), *Production Functions and Supply Analysis*. University of Minnesota Press, St. Paul.

Tripathi, A and A. R. Prasad (2008), "An Overview of Agrarian Economy in India: The Performance and Determinant". Paper Presented in National Seminar on Indian Economy in 21st Century: Prospects and Challenges organized by Department of Economics, Banaras Hindu University, Varanasi.

Van der Eng, Pierre. (1996), *Agricultural Growth in Indonesia: Productivity Change and Policy Impact Since 1880*. St. Martin's Press, New York.

Wen, G. L. (1993), "Total Factor Productivity Change in China's Farming Sector: 1952-1989". *Economic Development and Cultural Change* 42 (3): 427-445