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Productivity Growth in Indonesian Agriculture, 1961-2000

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Abstract

We use an index number approach to measure total factor productivity (TFP) growth in Indonesian crop and livestock agriculture between 1961-2000. A Tornqvist index is developed to minimize biases that may result from relative price changes in factor and output weights. The results indicate that agricultural TFP growth accelerated in the 1970s but was halted in the late 1990s. Agricultural productivity growth was not limited to rice but also extended to other food and horticultural crops.

Key words

Total factor productivity, Tornqvist index

Productivity Growth in Indonesian Agriculture, 1961-2000

I. Introduction

During the latter half of the 20th Century, rising output per hectare replaced expansion of cropland as the predominant source of agricultural growth in most of the world (Hayami and Ruttan 1985). 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 Indonesia during the last 40 years of the 20th Century. Although agriculture's share of the economy of Indonesia declined over this period, agriculture still provided the main livelihood for 50 percent of the nation's population, or over 100 million people, at the end of the Century. Sustaining productivity growth in agriculture continues to be critical for achieving food security, poverty reduction, and broad-based economic growth.

Assessing the productivity performance of the agricultural sector in Indonesia has been difficult due to data deficiencies, but significant improvements in agricultural input and output measurement have recently been provided by van der Eng (1996). In particular, van der Eng provides new and improved estimates of agricultural cropland in Indonesia. These estimates differ markedly from the agricultural land use provided by FAO, which has been the primary source of data used in previous assessments of productivity growth in Indonesia (see, for example, Mundlak et al. , 2002; Suhariyanto, 2001). In addition, previous assessment of agricultural growth have sometimes used changes in agricultural value-added rather than changes in output quantities, which confounds the effect of prices and quantity changes in growth measurement.

In this study, we use time series of 49 categories of crop and livestock outputs and 18 categories of inputs, with their respective prices, to construct a Tornqvist index of total factor productivity (TFP) between 1961 and 2000. 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, and technology (Alston, Norton and Pardey, 1995). Using a Tornqvist index reduces the common index number bias arising when price weights change over time. Recent studies of agricultural productivity growth in India (Fan, Hazell and Thorat, 1999) and China (Fan and Zhang, 2002) have found this approach to give significantly different results compared with TFP indices based on a constant set of aggregation weights.

What emerges from this exercise is a picture that raises concerns about future growth in Indonesia's agriculture, and the welfare of the people who depend on agriculture for their livelihood. Agricultural productivity in Indonesia's agriculture appeared to stagnate in the early 1990s after enjoying two decades of rapid growth. Poor weather and macroeconomic shocks during 1996-1998 exacerbated the poor performance of the agricultural sector. We conjecture that without major increases in public and private investments in Indonesia's agriculture, it will not return to a path of sustained productivity growth.

II. Methodology

Productivity can be defined as a ratio of the output to inputs used in production. An increases 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 increases 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).

A well-known limitation of index numbers is that changes in prices over time may lead to biases in the measurement of TFP because producers change the mix of inputs and outputs in production in response to price changes. To illustrate, Figure 1 shows the unit isoquant of a production function in which two inputs, *L* and *A*, are used to produce output *Q*. The ratio of input prices is given by W_0, and point *a* is the cost minimizing combination of *L* and *A* to produce a unit of *Q*. Technical change causes the unit isoquant to shift inward such that fewer inputs are required to produce a given amount of output. The new unit isoquant is *Q´*. The new input combination to produce *Q´* is given by point *b*. An index of productivity growth should measure the percent reduction in aggregate input (cost) needed to produce *Q*. However, if the price of *L* relative to *A* declines (from W_0 to W_1 in Figure 2), then the optimal input combination becomes point *c*. However, at the old relative price line W_0, *c* is more costly then *a*. Thus, if inputs are aggregated using the initial weights W_0, moving from point *a* to *c* would imply an increase in aggregate input used to produce one unit of *Q*. This would appear as a decrease in productivity although no change in the underlying technology actually occurred. On the other hand, if weights W_1 are used to aggregate inputs, then *c* is cheaper (uses less aggregate input) then *a*, implying an improvement in TFP. Similar problems are encountered in aggregating across multiple outputs (Alston, Norton and Pardey 1995).

The Tornqvist index minimizes the effect of changes in price weights on output and input aggregation by allowing the weights to adjust over time as prices change. The Tornqvist index of output for year t is defined as

Eq 1 $$\ln\left(Y_t / Y_{t-1}\right) = \sum_{i=1}^{n} \frac{\left(R_{i,t} + R_{i,t-1}\right)}{2} \ln\left(\frac{Y_{i,t}}{Y_{i,t-1}}\right)$$

Thus, the growth rate of aggregate output *Y* between period *t* and *t-1* is a sum of the growth rates of the *n* commodities which make up total output, each weighted by the average of their revenue share *R* during *t* and *t-1*.

Similarly, the aggregate input index is defined as

Eq 2 $$\ln\left(X_t / X_{t-1}\right) \;=\; \sum_{j=1}^{m} \frac{\left(S_{j,t} + S_{j,t-1}\right)}{2} \ln\left(\frac{X_{j,t}}{X_{j,t-1}}\right)$$

where the growth rate of aggregate input *X* between period *t* and *t-1* is the sum of the growth rates of the *m* categories of inputs, each weighted by the average of their factor share *S* during these periods.

The change in total factor productivity (TFP) between period *t* and *t-1* is then given as

Eq 3 $$\ln\left(\frac{TFP_t}{TFP_{t-1}}\right) \;=\; \ln\left(Y_t / Y_{t-1}\right) - \ln\left(X_t / X_{t-1}\right).$$

Estimation requires data on quantities and prices for each period. While output production and prices can usually be obtained, measurement of input changes is often more difficult. Estimates of the quantities and market or shadow prices of farm-supplied inputs such as land, family labor and animal power may be very imperfectly measured, even for one point in time let alone for a long time series.

An alternative approach for input aggregation is to estimate production elasticities and derive factor shares assuming profit-maximizing behavior of producers. In this study we use both an index number and production function approach for aggregating inputs in agricultural production. For the production function approach, we estimate a 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 *m* conventional inputs, the Cobb-Douglas function can be written as

Eq 4 $$Y \;=\; A \sum_{j=1}^{m} X_j^{\beta_j}$$

where A is an intercept term and β_j give the production elasticity of input j. Constant returns to scale implies $\Sigma\, \beta_j = 1$. Using a likelihood ratio test to compare the estimates of a regression with the CRS restriction imposed and an unrestricted equation provides a statistical test of returns to scale. Hayami and Ruttan (1985) found that estimates of agricultural production functions for developing countries tended to exhibit constant returns to scale, although Craig Pardey and Roseboom (1997) found evidence of decreasing returns to scale. When data is limited or subject to significant error, imposing this restriction reduces the number of parameters to estimate. Further, to reduce problems associated with multicollinearity, the Cobb-Douglas production function can be rewritten as

Eq 5 $$\frac{Y}{X_1} = A\, X_1^{\delta} \prod_{j=2}^{m} \left(\frac{X_j}{X_1} \right)^{\beta_j}$$

where $\delta = \sum_{j=1}^{m} \beta_j - 1$. Under constant returns to scale, $\delta = 0$. Letting X_1 be labor, this equation is an estimation of output per worker as a function of the number of workers and other inputs expressed in quantities per worker (or just non-labor inputs per worker if CRS is imposed). The estimates of $\beta_1, \beta_2 \ldots \beta_m$ can then be used as weights to construct the aggregate input index, as an alternative to the Tornqvist index for cases in which factor price data are unavailable or of questionable reliability.

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 is 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.

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 five categories (cropland, labor, animal stocks, fertilizers and agricultural machinery). 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 estimator is biased (Greene, 1993)

III. Data

The lack of reliable time series data agricultural production and input use in Indonesia has been a limiting factor in previous estimates to quantify productivity growth. Agriculture is generally defined to include crops, livestock, fresh and marine fisheries, and forestry. But most studies on agricultural productivity growth focus on crop and livestock agriculture due to serious deficiencies in measuring outputs and inputs used in fisheries and forestry (Craig, Pardey and Roseboom, 1997). This study follows this practice as well.

Measurement uncertainties also affect crop and livestock production and input use. On the output side, some studies (e.g., Arnade, 1998; Suhariyanto, 2001; Mundlak et al., 2002) have used national accounts of the value of agricultural production or value-added (GDP) as a measure of aggregate output. But using current value confounds quantity and price effects on changes in output. Further, deriving real changes in agricultural GDP depends critically on the choice of inflation deflator. For periods of high inflation such as during the early 1960s, CPI and GDP deflators available for Indonesia are subject to a wide margin of error. For inputs, FAO estimates of agricultural land in agriculture in Indonesia are highly suspect. While agricultural land is inherently difficult to define and measure, recent efforts by van der Eng (1996) has significantly improved the record of agricultural change in Indonesia.[1]

Crops and livestock output

FAO production data are used to measure outputs of food, horticultural and non-food crops, and meat, milk and eggs, since 1961.[2] Crop and livestock production is measured in metric tons net of seed and animal feed requirements.

Crop and livestock product prices

FAO producer prices are available for most commodities from the mid 1960s until 1995. The FAO producer price series are drawn from national statistics and may actually represent farmgate, rural or urban wholesale prices, depending on the country. VDE also supplies price series for several food and non-food crops which he calls 'rural bazaar

[1] In the remainder of the paper, data sources are represented by "FAO" for Food and Agricultural Organization's FAOSTAT series, "BPS" for statistics from the Indonesian Central Statistics Office, and VDE for data series reported in van der Eng (1996).

[2] BPS breaks down Indonesian agricultural GDP into five categories: food crops, non-food crops, animals, fisheries and forestry. Food crops include cereals, root crops, legumes, fruits and vegetables. Non-food crops include oil palm, rubber, coconut, sugar, tropical beverages, fiber crops, tobacco, spices and medicinal crops. Animal products include meat, milk, eggs, offal and hides. Non-food crops are sometimes referred to as cash crops, estate crops, or plantation crops, although they are mainly produced by small holders, are not the only agricultural commodities that provide farmers with cash income, and are partially consumed as food.

prices.'   Both the FAO and VDE price data are close to Jakarta wholesale prices reported in the BPS annual statistical yearbooks for major food and non-food commodities.   We use VDE series for food crops and several non-food crops and extend these series with BPS data through 2000. For horticultural crops, FAO series are used to 1995 and extended from 1996-2000 with price statistics published by the Ministry of Agriculture (namely, the *Vademekum* publications). Prices of animal products are FAO producer prices. All prices are normalized on the price of rice in a given year, and therefore output is measured in 'rice-equivalent' units. For commodity prices from 1961-1965 (for which FAO price series are not available), the average price (relative to rice) from 1966-1970 is used. Similarly, the average relative livestock product price during 1991-1995 is extended to the period 1996-2000. For some minor non-food crops such as spices (e.g., cloves, vanilla, nutmeg, cinnamon, and ginger), average national prices are from the Director General for Estates, Ministry of Agriculture.

Cropland

VDE estimates for cropland (which includes land area for paddy rice (*sawah*), land area for gardens and upland crops, and land area in non-food crops) are used through 1995 and extended with data from BPS for 1996-2000. The VDE series differs markedly from the FAO data series for cropland, but tracks fairly well the total crop area harvested reported by FAO (Figure 3). Using the FAO cropland series clearly overstates actually area in cropland during the 1960s and 1970s, and therefore understates the growth in conventional inputs in Indonesia during this period. Even the data for the 1980s and 1990s appears suspect. While VDE reports continued expansion of cropland in Indonesia throughout the closing decades of the 20th Century, it should be noted that almost all of the area expansion occurred outside of Java and Madura islands. The land frontier in densely populated Java and Madura was reached by the middle of the Century, and in recent years cropland in these islands has even declined somewhat due conversion of agricultural land to other uses.

Our Tornqvist input index includes two categories of land quality – irrigated and non-irrigated land. Irrigated land is from VDE and updated after 1995 from BPS. Since price series are unavailable for cropland, we follow Mundlak et al. (2002) and value irrigated land at 2.5 times the value of non-irrigated land. The service flow (price weight) from irrigated and non-irrigated cropland is then estimated as a residual – the remainder of total output after paying for agricultural labor, fertilizer, machinery services, and animal services.

Labor and wages

Two categories of labor are adult male and female workers employed in agriculture, and are from FAO. VDE provides another time series for agricultural labor but this is highly correlated with the FAO series. Daily wages for male and female workers are from VDE and refer to average wages paid by plantations. Agricultural wages are extended beyond 1995 from BPS. To find total annual labor costs, daily wages (in rice equivalents) are multiplied by 300 days worked/year for men and 250 days worked/year for women up to

1970. From 1971 onwards days worked per year is assumed to decline by 2 days each year to reflect the growth of non-agricultural employment by persons from agricultural households.

Fertilizer

Annual application of chemical fertilizer (N, P_2O_5, and K_2O) are from FAO. Prices paid for fertilizer are from VDE and updated from BPS. From the early 1970s until 1999, chemical fertilizer was heavily subsidized in Indonesia (sometimes by as much as 50 percent of actual cost). This raises the question whether fertilizer inputs should be weighted by their social or private costs. Private costs (excluding the subsidy) are used in this study to conform with the theory underpinning the index number approach to measuring productivity.[3] However, despite a rapid growth in fertilizer application during the last several decades, the factor share of fertilizer in total costs remains small. Even at the social cost of fertilizer, total (public and government) expenditures for fertilizer rarely exceeded 4 percent of the value of agricultural output.

Agricultural machinery

Agricultural machinery is measured in terms of horse-power available from tractors and threshers used in agriculture. Machinery includes two-wheel tractors, small, medium and large four-wheel tractors, and power threshers. Machinery data is from FAO supplemented with more detailed breakdown of machinery by type published by BPS. Machinery prices are import values (FAO) amortized over five years to get an annual service flow.

Livestock

Livestock contribute to agriculture in several ways. In addition to yielding meat and other animal products, they provide power, fertilizer, reproduction, and serve as a store of wealth. We measure livestock inputs as the total annual stock of buffalo, beef cattle, dairy cows, horses, pigs, small ruminants, and poultry. Data are from FAO and are aggregated using weights given in Hayami and Ruttan (1985). However, including the entire stock of animals mixes the power and breeding functions with what is essentially a measure of meat stocks. A more reasonable measure might be to include only animals used primarily for traction and breeding. However, we were unable to break down existing livestock data by these functions. Further, we were unable to identify reliable time series of animal services flows to provide weights for the livestock inputs. Therefore, to construct the input index we simply attributed a 20 percent factor share to livestock up to 1990 and assume the livestock share subsequently declined to 18 percent

[3] "If we assume that producers maximize profits, output markets are competitive, and the production technology is characterized by constant returns to scale, the elasticity of output with respect to each input is equal to its share in total costs. Then, TFP growth can be estimated using observed input and output quantities and prices" (Byerlee and Murgai, 2002, p. 229).

by 2000 as machinery gradual replaced livestock used for traction (over this period, machinery factor share increased from 1 percent to about 3 percent).[4]

IV. Results

Agricultural output growth

Indonesia produces a diverse set of agricultural commodities. Food crop production is dominated by rice, but also includes several secondary food crops, especially cassava and maize. Production of non-food crops includes rubber, oil palm, coffee, tea, cacao, sugar cane, coconut, and numerous other species. Poultry has been the fastest growing component of animal production, but large and small ruminants and pigs are also important. Besides crops and animal products, fresh water and marine fisheries and forestry are also important components of Indonesia's agricultural sector. Table 1 shows the changing level and composition of agricultural output in Indonesia since 1961. The first four columns report average output levels during the first half of each decade in terms of 'rice equivalents,' where commodities are valued and aggregated by their current price relative to the current price of rice. Between 1961-65 and 1991-95, total agricultural output increased from 46.9 million tons of rice-equivalent to 129.8 million tons. Rice was by far the most important commodity, accounting for about 26 percent of total agricultural output in the early 1960's and nearly 37 percent of total output in the early 1990s. Among non-food crops, oil palm grew very rapidly, especially after 1980. Meat and milk production also gained in output share. According to the figures, production of forest products hardly grew at all over the past four decades, but these figures are not very reliable.

In assessing overall growth of the Indonesian agricultural sector since the 1961, we distinguish between three periods. The first period, between 1961 and 1967, was a time of economic and political instability in Indonesia. Non-food crop production fell sharply following the nationalization of foreign-owned estates. Indonesian agriculture was probably operating inefficiently during this period, below the production function frontier. During the second period, between 1968 and 1992, Indonesia sustained rapid growth in both crop and animal production, with average annual output growth of around 4 percent. "Green revolution" technologies brought large increases in rice yields, and the area under non-food crops grew rapidly outside of Java. However, growth began to slow during the end of this period, and by the 1990s appeared to have stagnated. The third period, between 1993-2000, output growth averaged only 0.9 percent/year. Indonesia suffered from weather-induced and macroeconomic shocks during the latter part of the 1990s that exacerbated the slowdown in output growth, but this trend appeared to precede these shocks.

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[4] The 20 percent share assigned to livestock is taken from the production elasticities estimated for developing country agriculture reported in Hayami and Ruttan (1985). Hayami and Ruttan summarized findings from 10 studies which showed livestock production elasticity ranging from 0.10 to 0.30 (p. 149). We chose a mid-point of 0.2 from these estimates.

Indices of agricultural output are shown in Table 2 (agricultural production only includes crop and animal components, having excluding fisheries and forestry production due to unreliability of these data). The first index, based on agricultural GDP (value-added) from crops and livestock products, shows more rapid growth value-added GDP confounds price and quantity effects in measuring growth, and is sensitive to the choice of deflator. During the high inflation period of the 1960's, the value-added GDP index is highly variable. During the mid 1990s, crop-livestock GDP showed apparently rapid growth while the quantity-based indices show that output stagnated. It is possible that the growth in value of output (after discounting for general inflation) during the 1990s was primarily due to prices effects, and not increases in quantity.

The other three indices give very similar results for changes in agricultural output for Indonesia. The FAO production index uses a Laspeyres index formula with a fixed set of global price weights, while our Paasche and Tornqvist indices are based on local Indonesian commodity prices. It appears that using a fixed set of national or global weights to aggregate output does a reasonably good job of measuring output growth in Indonesian agriculture. The Tornqvist index measures a 260 percent increase in agricultural output between 1961 and 2000, while the Paasche and FAO indices showed an increase of 254-5 percent.

Agricultural input use

Table 3 provides a breakdown of inputs used in Indonesian agriculture during each of the past four decades, plus average annual growth rates over the entire period and during the three periods of instability, growth, and stagnation described above. Cropland continued to expand at about 2 percent per year throughout the entire period, even to the end of the Century. Virtually all cropland expansion occurred outside of Java, especially in the relatively sparsely populated islands of Kalimantan, Sumatra and Sulawesi. Irrigated cropland expanded at 1.8 percent per year during 1962-2000, slightly less than the overall growth in cropland. The agricultural labor force also grew continuously over the four decades, and was still growing at about 1 percent per year in the 1990s. However, this probably overstates actually growth in labor input as many agricultural households expanded their non-farm activities. This was especially true in Java where average farm size is only about 0.2 hectares per household. Although much of this land is double or even triple cropped, it is generally insufficient to productively employ available family labor year-round and household members often engage in off-farm jobs, crafts or petty trading.

The number of farm animals grew by an average of 2.3 percent/year during 1961-2000, but growth was highly variable within this period. A large share of this growth was in poultry which relied heavily on imported feeds. The number of livestock fell sharply in the economic crisis of 1997-98 when the cost of imported feeds skyrocketed as the Rupiah most of its value.

Growth in industrial inputs used in agriculture, namely, fertilizer and machinery, was very rapid, averaging more than 10 percent/year between 1961 and 2000. However, use of these inputs started from a very small base, and industrial input use per hectare remained small relative to Asian standards (Mundlak et al. 2002). Since 1993 there was virtually no growth in fertilizer use, and per hectare application actually declined. The slowdown in fertilizer use can be partly attributed to rising real costs to farmers. The level of fertilizer subsidy was as much as 50 percent from the mid-1970s to the mid 1980s, but then declined gradually and was finally ended in 1999.

Cobb-Douglas estimates for Indonesian agriculture

OLS estimates of a Cobb-Douglas production function for Indonesian agriculture are presented in Table 4. For this estimation, irrigated and unirrigated cropland were aggregated into one cropland variable (with one hectare irrigated land weighted 2.5 times one hectare of unirrigated land). Male and female labor inputs were also aggregated, weighted by wage differences and our assumptions on declining days worked in agriculture per worker over time. The other inputs are animal stocks, chemical fertilizers and agricultural machinery horsepower. Constant returns to scale are imposed on the model to reduce the number of free parameters to estimate to four. With constant returns to scale, the estimated production elasticities sum to one.

All of the conventional inputs contributed significantly to labor productivity (at the 1% significance level) except the stock of animals. The production elasticity of land is 0.346, virtually the same as Craig, Pardey and Roseboom's (1997) estimate of 0.35 for agricultural land in developing countries. The production elasticity of labor is 0.379, which is high relative to estimates from other developing countries. It may be that the labor coefficient is capturing some of the contribution of animal stocks to production, as these variables are correlated, and the latter is probably poorly measured.

Profit maximization in competitive markets predicts that the estimated coefficients should approximate factor shares. For the modern industrial inputs, fertilizer and machinery, estimated production elasticities are significantly higher than actual factor shares, a finding also reported by Mundlak et al. (2002). Further, the estimates of the fertilizer and machinery elasticities were robust for several model specifications. For fertilizer, the production elasticity of 0.182 was several times higher than its average factor share of only 0.013. The production elasticity of machinery horsepower, 0.096, was also far above its average factor share of 0.019. Craig, Pardey, and Roseboom (1997) suggest that the high production elasticities often estimated for modern inputs in developing country agriculture partially capture the effects of new technology. The rapid expansion in the use of these inputs took place at the same time that new technology became widely available. The development and spread of new crop varieties that were responsive to higher doses to fertilizer and irrigation, for example, provided strong incentives for farmers to increase fertilizer use. Another contributing factor to the apparent underutilization of fertilizer in Indonesian agriculture may have been inadequate supply and credit constraints. Since the 1960s Indonesian national policy promoted the development of a domestic fertilizer industry and restricted imports, which limited domestic supply and may have created excess demand and led to implicit rationing of fertilizer (Mundlak et al., 2002).

Further evidence on input productivity implied by the production elasticity estimates is given in Table 5. The table shows the average and marginal products of inputs using average input and output quantities during 1961-65 and 1991-95. Output is given in tons of ‘rice equivalents.’ Changes between these periods reflect the application of improved technology and increased used of modern industrial inputs. Average and marginal products of traditional inputs (land and labor) increased, while marginal productivity of industrial inputs fell as their use greatly expanded. Based on production and input levels during 1991-95, each additional hectare of unirrigated cropland increased agricultural output by 1.09 tons of rice-equivalent, each additional male laborer increased production by 0.84 tons, and an additional ton of fertilizer applied increased output by 7.6 tons. Comparing marginal products to prices suggests that agricultural labor was paid above its marginal product, while fertilizer and horsepower were paid below their marginal product. Mundlak et al. (2002) found similar results for input productivity in Indonesian agriculture. However, the price ratios for land and labor fall within a 95% confidence interval for the marginal products. But these findings do imply that there continue to be strong economic incentives for Indonesian farmers to increase use of modern industrial inputs and that these adjustments will continue to be an important source of productivity growth for Indonesian agriculture in the coming years.

In the lower half of Table 5 we recalculate the Cobb-Douglas production elasticities assuming a coefficient of 0.20 for livestock (to preserve constant returns to scale, we reduce the estimates of the other coefficients by 20 percent). An elasticity of 0.20 for livestock is derived from a review of production function estimates for developing country agriculture in Hayami and Ruttan (1985). From more than 10 multicountry studies of developing county agriculture, they reported a range in estimates of livestock production elasticity between 0.10 and 0.30. We simply took a mid-value from this range. The revised estimates do not change the overall picture. They show that cropland appears to be paid close to its marginal product, labor somewhat above its marginal product, while fertilizer and machinery appear to be greatly underemployed.

Table 6 shows trends in aggregate input use in Indonesian agriculture. The Tornqvist index is based on actual factor shares paid for inputs, while the Paasche index uses average real input prices during 1996-2000 as fixed weights on input quantities. The Cobb-Douglas index uses the estimated production function elasticities as weights on the rate of growth in individual inputs. The Tornqvist index shows that aggregate input use increased by 103 percent between 1961 and 2000, just slightly more than the increase given by the Paasche index (99 percent). The Cobb-Douglas index shows a much higher rate of input growth (145 percent over the period) compared with the Tornqvist and Paasche indices because of the higher weight given to modern industrial inputs, which grew at a higher rate than traditional inputs over the period of study.

Agricultural TFP

With estimates of aggregate outputs and inputs, the index of total factor productivity (TFP) for Indonesian agriculture is found by simply taking the ratio of the output index to the input index. Three TFP indices are presented in Table 7 and Figure 4. The Tornqvist index uses factor shares to weight the growth in inputs and outputs. The Paasche index uses end-period prices of inputs and outputs as aggregation weights. The Cobb-Douglas index uses revenue shares to weight output growth and the production elasticities estimated from the Cobb-Douglas function to weight input growth. Because the Cobb-Douglas index gives higher weight to modern industrial inputs (use of which rose rapidly over the period), it registers higher growth in aggregate input use and thus less growth in TFP compared with the other indices. The Tornqvist and Paasche index give similar results, and indicate that TFP grew by just under 80 percent between 1961 and 2000.

All three TFP indices suggest that TFP growth was very slow during the early 1960s but began a period of rapid growth of about 2 percent per year from the late 1960s to the 1980s. Growth in TFP began to slow markedly, however, toward the end of the 1980s and stagnated in the 1990s. In fact, there was very little growth in TFP in Indonesian agriculture in the 1990s.

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 8 summarizes these results. Between 1961-2000, the average annual growth in agricultural crop-livestock production in Indonesia was 3.4 percent, of which 1.9 percent was due to increases in land, labor, and other conventional inputs and 1.5 percent was due to improvements in total factor productivity. Increases in TFP were most evident from 1968-1992, but there was little change in TFP either before or since these years. The growth in agricultural output since 1993 (about 1.1 percent per year) is due almost entirely to increases in land and labor inputs in agriculture.

Output per agricultural worker increased by an average of 2.1 percent per year between 1961-2000. Most of this was due to increases in output per hectare of cropland, but cropland per worker also increased throughout the period. In fact, land per worker grew by about 1 percent per year even up to the end of the Century despite the continued increase in the number of workers employed in agriculture. Virtually all of the land expansion occurred outside of Java and Madura, especially on the relatively sparsely populated islands of Kalimantan, Sumatra and Sulawesi.

The final rows of Table 8 give some indicators of food security in Indonesia by comparing growth in food production to population growth. By these measures Indonesia’s food economy preformed remarkable well during the final decades of the 20th Century. Domestic food production per capita grew at an annual rate of 2.6 percent during 1961-2000. Rice production per capita grew even more rapidly, at 3.0 percent/year. However, per capita food production went into decline in the 1990s, when TFP growth in Indonesian agricultural stagnated.

V. Conclusions

Recent improvements in the data series for Indonesian agriculture provide an opportunity to reassess the productivity performance of this sector during the closing decades of the

20th Century. By constructing a Tornqvist index of input, output, and total factor productivity growth we are able to minimize the bias inherent in index measures when price weights change over time. Our estimation showed that between 1961 and 2000, output in crop and livestock commodities in Indonesia grew at an annual rate of 3.4 percent, utilization of conventional inputs in agriculture (cropland, labor, livestock, fertilizers, and machinery) increased by 1.9 percent, and TFP grew by 1.5 percent. Growth in the use of modern industrial inputs (chemical fertilizers and power machinery) grew rapidly from very low initial levels, though still appeared to be significantly underutilized when comparing their cost to marginal productivity. Nearly all of the growth in TFP, however, occurred between 1968 and 1992. Agricultural growth in the 1990s relied almost entirely on increased in conventional factors while growth in productivity stagnated.

While a careful examination of the underlying causes of the productivity slowdown in Indonesian agriculture is beyond the scope of this study, we can suggest some probable culprits. Draught-causing El Nino and macroeconomic shocks took their toll on agricultural production in the late 1990s (1996-1998 especially), but the slowdown in productivity appeared to precede these events, and has continued since then. More important for long-term sustainable agricultural growth in Indonesia is to increase productivity-enhancing investment in the agricultural sector. As Figure 5 shows, both government spending and private investment in agriculture in Indonesia fell in the 1990s as a percentage of agricultural GDP. The downward trend in public spending for agricultural development since the mid-1980s is particularly alarming, as nearly all spending for agricultural research and extension in Indonesia is by the government (Fuglie, 1999). 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 Indonesian 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 Indonesian economy.

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Table 1. Level and composition of agricultural output in Indonesia

	Average quantity during period				Average annual growth rate during period			
	1961-65	1971-75	1981-85	1991-95	1961-00	1961-67	1968-92	1993-00
	(millions of tons of 'rice equivalents')				(%)			
Agriculture outputs, total	46.9	62.1	89.1	129.8	2.9	0.8	4.0	0.9
Crop and animal outputs, total**	31.0	44.2	68.2	102.0	3.5	1.3	4.8	1.0
Food crops, all	18.6	27.7	44.4	60.3	3.4	1.3	5.1	-0.1
Rice, paddy	12.4	21.2	35.8	47.5	3.9	1.7	5.5	0.7
Cassava	2.3	2.3	2.6	3.2	1.2	-0.5	1.9	0.2
Maize	1.5	1.5	2.4	3.8	7.1	11.3	7.8	1.6
Horticultural crops, all	5.5	7.8	9.3	14.2	3.3	2.7	3.3	3.9
Fruits, all	4.6	7.2	9.0	12.7	3.7	3.0	3.7	4.3
Vegetables, all	2.5	3.5	3.9	7.7	3.8	2.9	4.0	3.9
Non-food crops, all	5.1	6.4	10.6	19.2	4.1	0.8	5.3	2.9
Cane sugar	1.1	1.5	2.4	3.6	2.9	1.4	5.6	-4.1
Rubber	1.7	2.0	2.4	3.6	2.1	0.4	2.8	0.8
Palm oil	0.2	0.4	1.3	4.5	10.6	2.6	12.7	10.0
Animal products, all	2.6	3.5	5.9	11.7	4.1	1.4	5.7	0.9
Meat	2.5	3.4	5.7	11.2	4.3	1.5	6.0	0.8
Milk	0.4	0.6	1.7	3.3	3.8	-0.6	5.1	2.9
Fish products, all	2.9	3.9	6.4	11.1	4.4	4.6	4.4	4.3
Forest products, all	12.3	12.8	12.4	13.2	-0.5	-1.5	0.7	-3.5

**Net of seed and feed

Table 2. Indices of agricultural output for Indonesia

	Tornqvist Index based on revenue shares	Paasche Index based on end period prices	FAO (Laspeyres) Index based on global set of prices	Index of Value-Added based on current prices
1961	1.00	1.00	1.00	1.00
1962	1.05	1.07	1.08	1.44
1963	1.01	1.02	1.02	1.41
1964	1.05	1.08	1.08	1.29
1965	1.05	1.07	1.07	0.66
1966	1.08	1.10	1.11	1.03
1967	1.05	1.06	1.06	1.36
1968	1.21	1.22	1.21	1.77
1969	1.24	1.24	1.23	1.98
1970	1.32	1.33	1.31	2.10
1971	1.37	1.37	1.34	2.10
1972	1.38	1.37	1.35	1.84
1973	1.47	1.47	1.46	2.07
1974	1.52	1.53	1.51	1.97
1975	1.54	1.54	1.50	1.95
1976	1.56	1.56	1.50	1.95
1977	1.62	1.61	1.56	2.05
1978	1.70	1.71	1.66	2.25
1979	1.79	1.78	1.74	2.22
1980	1.95	1.93	1.89	2.38
1981	2.08	2.07	2.01	2.63
1982	2.07	2.04	1.97	2.82
1983	2.21	2.18	2.14	2.87
1984	2.39	2.37	2.33	3.02
1985	2.48	2.45	2.40	3.18
1986	2.63	2.59	2.53	3.30
1987	2.67	2.62	2.56	3.56
1988	2.81	2.74	2.70	3.88
1989	2.93	2.86	2.83	4.16
1990	3.07	3.00	2.96	4.01
1991	3.10	3.04	2.99	3.81
1992	3.30	3.25	3.22	4.03
1993	3.35	3.29	3.27	3.97
1994	3.34	3.28	3.29	4.03
1995	3.58	3.52	3.51	4.40
1996	3.64	3.59	3.58	4.61
1997	3.54	3.47	3.45	4.88
1998	3.53	3.47	3.43	5.40
1999	3.58	3.51	3.44	5.62
2000	3.61	3.55	3.54	5.33

Table 3. Inputs used in Indonesian agriculture

	Average quantity during period				Average annual growth rate during period			
	1961-65	1971-75	1981-85	1991-95	1961-00	1961-67	1968-92	1993-2000
Cropland (million hectares)	17.55	18.91	26.02	32.25	1.99	0.31	2.35	2.12
Area harvested (million hectares)	17.52	19.62	22.66	28.35	1.67	1.10	2.08	0.84
Irrigated cropland (million hectares)	2.42	2.66	3.31	4.56	1.78	1.44	2.34	0.30
Ag labor (million workers)	28.61	31.70	37.55	46.01	1.46	0.76	1.74	1.10
Fertilizer (million tons/year)	0.12	0.43	1.67	2.46	10.56	1.65	16.04	0.13
Ag machinery (mil. horsepower)	0.07	0.16	0.19	0.58	11.52	7.45	14.31	5.88
Animals (million head of stock)	10.53	10.87	14.73	24.79	2.25	-0.11	3.63	-0.26
Fertilizer/Cropland (kg/ha)	6.91	22.73	64.03	76.26	8.51	1.31	13.59	-1.98

Table 4. Cobb-Douglas production function estimates for Indonesian agriculture

Variables	Coefficients	Standard Error	t Statistic	P-value	95% CI for coefficient Lower bound	95% CI for coefficient Upper bound
Intercept	-1.738	0.070	-24.696	0.000	-1.881	-1.595
Labor	0.379	0.118	3.223	0.003	0.140	0.618
Cropland	0.346	0.135	2.573	0.014	0.073	0.619
Fertilizer	0.182	0.012	14.666	0.000	0.157	0.207
Machinery	0.096	0.018	5.184	0.000	0.058	0.133
Livestock	-0.003	0.065	-0.048	0.962	-0.136	0.129

Regression Statistics	
Multiple R	0.996
R Square	0.992
Adjusted R Square	0.991
Standard Error	0.033
F Statistic of Regression	1121.022
Significance of F	0.000
Observations	40.00

Table 5. Input productivity implied by the Cobb-Douglas production elasticity estimates

Based on OLS estimates of production elasticities

Variables	Production elasticity	Average input quantity 1961-65	Average input quantity 1991-95	Average product 1961-65	Average product 1991-95	Marginal product 1961-65	Marginal product 1991-95	Input-output price ratio*
Labor	0.379	28.61	46.01	1.08	2.22	0.41	0.84	1.07
Cropland	0.346	17.55	32.25	1.77	3.16	0.61	1.09	1.01
Fertilizer	0.182	0.12	2.46	255.96	41.47	46.59	7.55	0.71
Machinery	0.096	0.07	0.58	436.29	174.50	41.70	16.68	0.30
Livestock	-0.003	10.53	24.79	2.95	4.11	n.a.	n.a.	0.84

Adjusted OLS estimates **

Variables	Production elasticity**	Average input quantity 1961-65	Average input quantity 1991-95	Average product 1961-65	Average product 1991-95	Marginal product 1961-65	Marginal product 1991-95	Input-output price ratio*
Labor	0.304	28.61	46.01	1.08	2.22	0.33	0.67	1.07
Cropland	0.277	17.55	32.25	1.77	3.16	0.49	0.88	1.01
Fertilizer	0.146	0.12	2.46	255.96	41.47	37.27	6.04	0.71
Machinery	0.076	0.07	0.58	436.29	174.50	33.36	13.34	0.30
Livestock	0.200	10.53	24.79	2.95	4.11	0.59	0.82	0.84

*average real price during 1991-95 in input per ton of 'rice equivalent'. Livestock price based on factor share of 0.20. Land price is residual.

** livestock elasticity fixed at 0.20 and other estimates reduced by 20%.

Table 6. Trends in aggregate input use in Indonesian agriculture

	Tornqvist Index based on actual factor shares	Production Fn Index based on Cobb-Douglas prod. elast.	Paasche Index based on end-period factor prices
1961	1.00	1.00	1.00
1962	1.01	1.02	1.01
1963	1.01	1.00	1.01
1964	1.01	0.95	1.01
1965	1.03	0.95	1.03
1966	1.03	1.03	1.03
1967	1.03	1.01	1.03
1968	1.07	1.17	1.06
1969	1.05	1.09	1.05
1970	1.05	1.15	1.05
1971	1.07	1.15	1.07
1972	1.09	1.30	1.07
1973	1.09	1.33	1.08
1974	1.11	1.35	1.10
1975	1.12	1.36	1.11
1976	1.14	1.39	1.13
1977	1.17	1.47	1.16
1978	1.21	1.57	1.20
1979	1.23	1.62	1.22
1980	1.26	1.73	1.24
1981	1.30	1.82	1.28
1982	1.34	1.87	1.33
1983	1.42	1.89	1.40
1984	1.48	1.99	1.45
1985	1.51	2.02	1.48
1986	1.56	2.06	1.52
1987	1.62	2.14	1.59
1988	1.67	2.22	1.63
1989	1.71	2.22	1.67
1990	1.77	2.29	1.73
1991	1.80	2.25	1.75
1992	1.86	2.31	1.81
1993	1.88	2.27	1.83
1994	1.93	2.34	1.88
1995	1.97	2.38	1.93
1996	2.02	2.43	1.98
1997	2.02	2.36	1.98
1998	2.01	2.48	1.96
1999	2.00	2.46	1.95
2000	2.03	2.45	1.99

Table 7. Index of total factor productivity (TFP) for Indonesian agriculture

	Tornqvist Index based on actual factor shares	Production Fn Index based on Cobb-Douglas prod. elast.	Paasche Index based on end-period factor prices
1961	1.00	1.00	1.00
1962	1.04	1.03	1.06
1963	0.99	1.01	1.01
1964	1.03	1.11	1.06
1965	1.02	1.11	1.04
1966	1.04	1.05	1.07
1967	1.02	1.04	1.03
1968	1.12	1.03	1.15
1969	1.18	1.14	1.19
1970	1.25	1.14	1.27
1971	1.27	1.19	1.29
1972	1.27	1.06	1.28
1973	1.35	1.10	1.37
1974	1.37	1.13	1.39
1975	1.38	1.13	1.38
1976	1.37	1.12	1.37
1977	1.38	1.10	1.39
1978	1.41	1.09	1.43
1979	1.45	1.10	1.47
1980	1.55	1.13	1.55
1981	1.60	1.14	1.61
1982	1.54	1.10	1.54
1983	1.55	1.16	1.56
1984	1.62	1.20	1.63
1985	1.64	1.23	1.66
1986	1.68	1.28	1.70
1987	1.65	1.25	1.65
1988	1.69	1.27	1.69
1989	1.71	1.32	1.71
1990	1.73	1.34	1.73
1991	1.72	1.37	1.73
1992	1.78	1.43	1.79
1993	1.78	1.48	1.79
1994	1.73	1.42	1.75
1995	1.81	1.50	1.83
1996	1.80	1.50	1.81
1997	1.75	1.50	1.76
1998	1.76	1.42	1.77
1999	1.79	1.46	1.80
2000	1.77	1.47	1.79

Table 8. Productivity change in Indonesian agriculture

	Average annual growth rate (%)			
	1961-2000	1961-67	1968-92	1993-00
Total outputs (crop and animal)	3.4	0.9	4.7	1.1
Total inputs	1.9	0.5	2.4	1.0
Total Factor Productivity	1.5	0.4	2.2	0.1
Labor productivity	2.1	0.5	3.1	0.1
Land productivity	1.6	0.9	2.6	-0.9
Land/worker	0.5	-0.4	0.6	1.0
Food crop output/population	2.6	0.2	4.1	-0.5
Rice output/population	3.0	0.7	4.6	-0.1

Figure 1. Index numbers and technical change

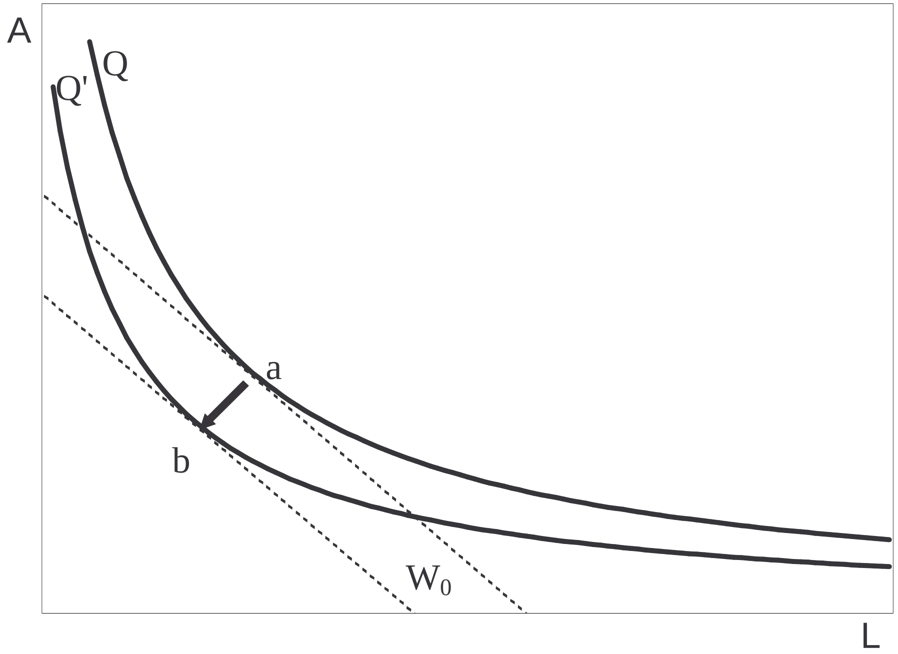

Figure 2. Biases in TFP when producers change the mix of inputs

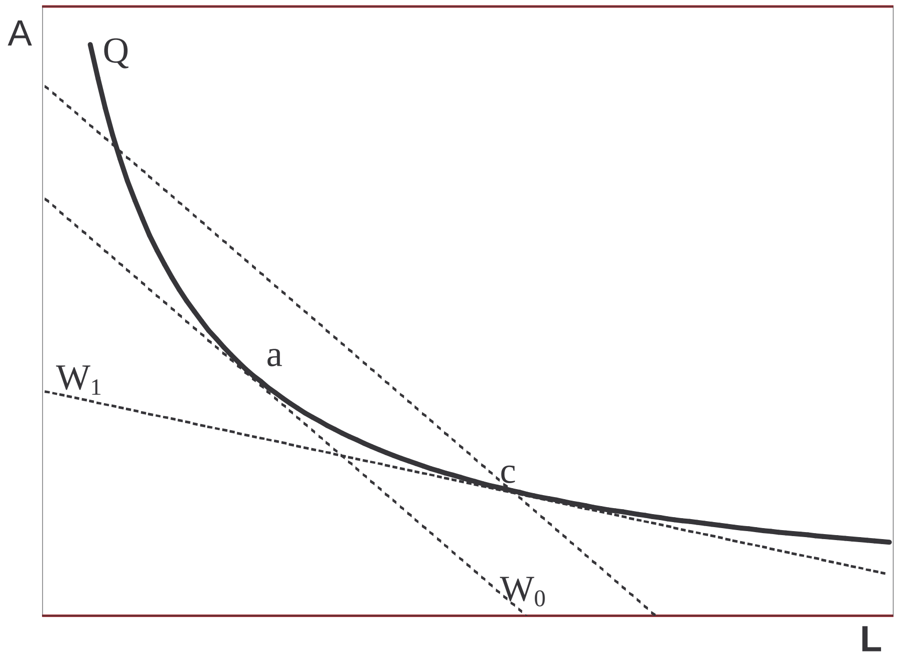

Figure 3. Alternative measures of cropland in Indonesian agriculture

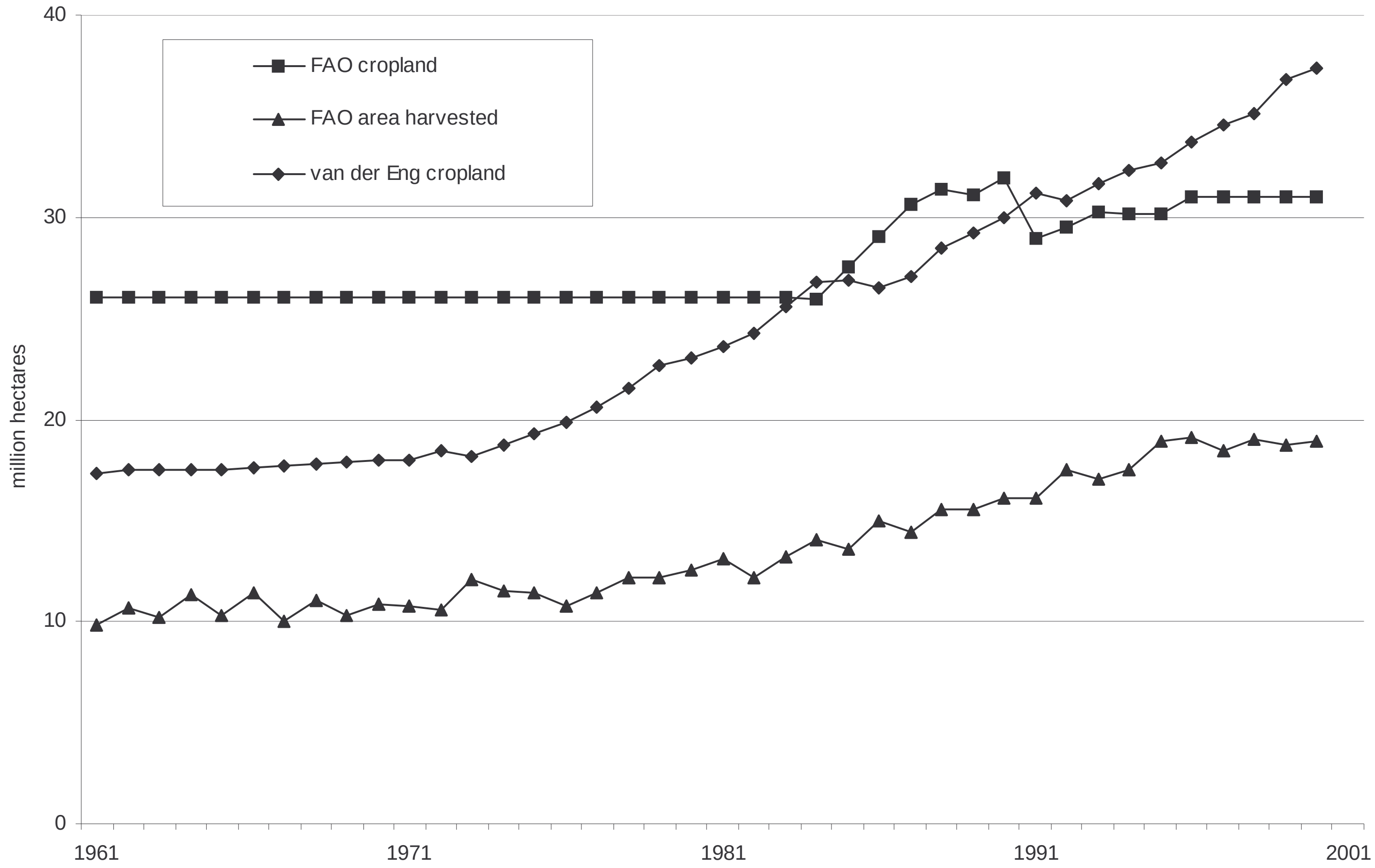

Figure 4. Total factor productivity (TFP) in Indonesian agriculture

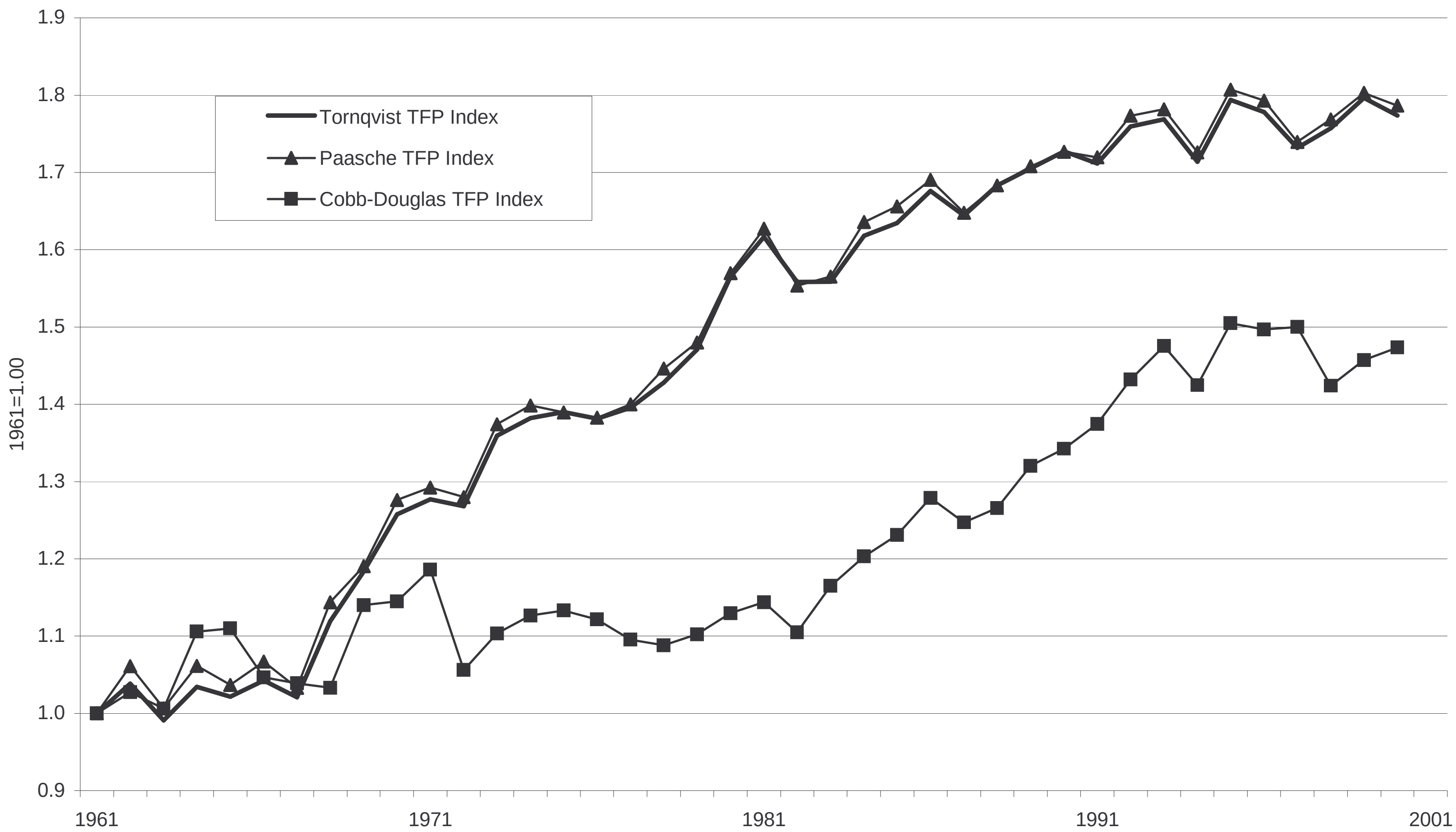

Figure 5. Trends in public and private investment in Indonesian agriculture